MECHANICS' MAGAZINE.

VOLUME IX—No. 4.] APRIL 1, 1837. [WHOLE NUMBER, 52.

TRANSACTIONS OF THE INSTITUTION OF CIVIL ENGINEERS.

It is seldom that we are enabled to give our readers so great a treat, as they will have in the perusal of the papers from this valuable work.

It is well known, that the most eminent engineers in England have formed an Institution for the advancement and improvement of Civil Engineering as a profession. The papers read before the society, some by the most distinguished members of the profession, have been collected in the elegant and costly work now before us, but few copies of which are in the United States.

We hasten to lay before our readers the various papers, as rapidly as the cuts can be prepared.

The expense of the work and its scarcity, will prevent the members of the profession (with but few exceptions) from obtaining even a sight of the Vol., we have therefore, without hesitation, determined to give as great a circulation to its usefulness as possible, though the expense incurred is not trifling, while our readers are enabled to have before them the cream of a work, costing double our yearly subscription, and not to be had for that, as it is only furnished to the few subscribers in this country.

We have already endeavored to give whatever may be new and useful to the profession, and our exertions shall not be intermitted,—the present No. is given as a guarantee of our promise.

We give in this No. the following papers:

On procuring supplies of Water for Cities and Towns, by boring. John Seaward, Esq., M. Inst., C. E.

Some account of several sections through the Plastic Clay formation, in the vicinity of London. William Gravatt, Esq., F. R. S., M. Inst., C. E.

Some account of Boring for Water in London and its vicinity. John Donkin, Esq., M. Inst., C. E.

ON PROCURING SUPPLISES OF WATER FOR CITIES AND TOWNS, BY BORING. COMMUNICATED BY MR. JOHN SEAWARD, M. INST. C.E.

A French gentleman of our anquaintance having recently addressed upon a project of supplying the different towns of France with water, by means of boring in the earth, according to the method which has come lately a good deal into fashion in different parts of England, and thus having brought the subject under our mature deliberation; we offer the following remarks, which we were led to give in reply, with the hope that they may be found not altogether uninteresting to the Institution.

In the first place, as respects the project of furnishing water to the different towns of France by means of simply boring in the earth; if by this is intended that the various towns are to be supplied with water economically, for all domestic and manufacturing purposes, in the same abundant manner that it is furnished to the inhabitants of London and other towns of England, we must at once declare without any hesitation that, as a general principle, the scheme will be abortive, and if attempted will infallibly end in loss and disappointment.

In stating thus explicitly our opinion, we do not wish to be understood as being anywise unfavorable to boring in general; on the contrary, as an art when employed under suitable circumstances, we know that it can be made, on various occasions, highly subservient to the wants of man, but we also know that with many persons, a very erroneous opinion prevails as to the economy, and other merits and advantages of the art.

The method of "simple boring," as it is called, is not adapted for all situations and

heavens; tanks and reservoirs, (similar to those employed in feeding navigable canals,) should be formed in convenient situations, to receive the rain-water which falls on the adjacent hills: either of these means would furnish an abundant supply of this necessary element constantly and economically.

It is perfectly true, that a populous town may be so situated as to be at an inconvenient distance from any salubrious river or brook, whence to obtain water, and local circumstances may be such as to render it impossible or inexpedient to form in the vicinity tanks or reservoirs to collect the rain-water from the hills; in this case, there appears to be no alternative but that of obtaining a supply from the bowels of the earth: in such case, it will be necessary to sink very capacious wells or shafts to a great depth, with suitable pumps and steam-engines, to bring the water to the surface; and even then the supply may be so scanty as to render it necessary to drive (in various directions) horizontal levels or galleries from the bottom of the wells or shafts, in order to break in upon the springs which may exist at a distance; similar to the method practised in the salt-works of England, to obtain a copious supply of the brine; but in such case to expect that by simply boring down into the earth, a plentiful supply of water can be obtained for the domestic and manufacturing purposes of a populous town, is to expect what rarely or never can be accomplished.

The modern plan of boring to obtain water has been, without any rational grounds cried up as a new and wonderful discovery, but the truth is, that boring is an operation of great antiquity; the miner and collier make use of it in a variety of ways, and it has from time immemorial been a useful auxiliary to the well-digger; he employs this process to discover where springs of water exist. By this means he can at a comparatively small expense determine whether the situation is favorable or not for forming a well; at the same time he can ascertain the quality of the water when obtained, and the probable ultimate expense which must be incurred in order to secure a regular supply.

In some instances it has happened that in boring, from the cause just stated, the water has of its own natural force risen up through the hole, and flowed over the surface in considerable quantity, and thus, without much further trouble or expense, a tolerably copious supply has been obtained. This circumstance is not generally met with; London and the surrounding district, wherein this art has been most successfully practised, is highly favored in this particular; the stratum of soil is a bed of clay, varying from 100 to 200 feet thick, and is therefore very easily bored through. It is remarkable that the springs under the bed of clay produce the finest and most salubrious water, while those above the bed of clay produce water so impure as to be unfit even for the most ordinary purposes. It is therefore easy to conceive, that this method would here meet with the most favorable encouragement, but in districts where the same circumstances do not exist, there would not be the same inducement to follow it.

"Simple boring," is suitable only when the quantity of water required is comparatively small: thus if the object be to furnish a very superior water for a nobleman's mansion, for a small village or neighborhood, or even for a single manufactory, then this method is admirable, provided the circumstances are in any proportion as favorable as in the district which surrounds London; but if the question be to provide an abundant supply of water for a large town or populous city, then certainly in every case, the method of boring should, on the score of economy, be the last that ought to be resorted to for the purpose.

That the bowels of the earth contain springs of water in abundance, there can be no doubt; miners and colliers are aware of this fact to their cost and sorrow: but we know full well that those same springs, if they have sufficient natural force, must find their way to the surface of the earth somewhere, without any boring, and then form rivers and flowing brooks. Why then delve a great depth at an infinite expense, to procure that which we can generally obtain so readily and economically on the surface of the earth?

There is scarcely a city or town of any magnitude but what has some fine river or copious brooks in its immediate neighborhood, these are the natural sources whence we should obtain our supply of water; but if the streams in the vicinity are so impregnated with deleterious matter, as to render the water unfit for domestic or manufacturing purposes, and if no ready method can be adopted for cleansing it, recourse should then be had to the water that falls from the

cumstance it is that has brought into favor the idea of depending on simple boring alone as a regular systematic method of obtaining a supply of water; and it is but right to say, that the method, in many instances, has been remarkably successful; but it should be borne in mind, that the supply, copious as it is called, has scarcely in any one instance exceeded what would be required for a moderately extensive manufactory, or for the domestic use of a very small village; moreover although considerable success has attended many of the experiments made to obtain water in this way, yet it is most certain that, as regards the obtaining of an abundant supply by the simple process of boring alone, in a majority of cases, the method has *completely failed;* and, after a very heavy and useless expense and loss of time has been incurred in these failures, recourse has at length been had, either *partially or wholly*, to sinking a well.

The most rational plan for obtaining a good supply of water from under-ground is in the first place to sink a well to about half the depth at which it is supposed the spring of water exists: thus, if the spring is judged to be 100 yards below the surface, then the well may be made 50 yards deep; this being properly built up and secured, the engine erected, and suitable pumps fixed, the remainder of the depth to the spring may be pierced through by the process of boring, and in this way a copious supply of water is frequently obtained, and as may be readily judged, the quantity of water obtained will vary according to the greater or less depth to which the well is formed; but at the same time it should be observed, that the deeper the well, the greater will be the expense of raising the water to the surface.

If necessary we could here enumerate a long list of losses, failures, and consequent disappointments, which have attended the process of boring, within our own observation; for the present, however, we shall confine ourselves to two instances.

About four years ago we erected, almost in the heart of the metropolis, a 14-horse condensing engine for a manufacturing purpose. As a good supply of water was wanted for that and other objects, the proprietor of the establishment thought he could obtain this necessary element on his own premises, and make himself independent of the water-companies. We recommended him to sinka well at once; but contrary to our advice, he determined to try the process of simple boring, the situation of his premises being judged very favorable for that purpose. A hole was consequently bored to about 100 yards deep, and after some labor and expense water was obtained, but the supply was so scanty as not to be half sufficient for the 14-horse engine; several attempts were made to remedy this but without effect; the hole was at length abandoned, and a well was then formed, though not so deep as it should have been; boring was then resumed to the depth of what was considered the main spring; pumps were put down the well, and water was again obtained; but even after all, the supply was barely sufficient for the engine. The result of this business was, that the proprietor after having his premises in confusion for nearly two years, in the end expended double as much money as would at once have formed a good productive well, and the interest of the money expended is considerably more than he would have had to pay to any water-company for all the water he required for his engine and manufactory, besides losing a considerable portion of the power of his engine, which is expended in drawing the water to the surface.

Within a quarter of a mile of the above-described well was situated a brewery furnished with a similarly-constructed well, from which a considerable supply of water had been obtained; it is, however worthy of remark, that no sooner did our engine commence drawing water from the new-formed well, than the brewers immediately lost a great part of the supply they had previously been accustomed to derive from theirs; the consequence was, they were under the necessity of sinking it deeper, and of putting up more powerful pumps, in order to obtain their former supply.

We mention the above fact to show that, although there is no question but it is possible to find a spring of water in almost any situation, yet the springs do not furnish that inexhaustible supply of water which some persons imagine; indeed a bare consideration of what is accomplished in mines and collieries must convince us of the truth of this fact; were the springs of that inexhaustible nature some pretend, not a single mine or colliery in the universe could be worked to any moderate extent whatever.

The second instance of failure in boring, which has happened in our own practice, we

shall now proceed to relate. About twenty years ago a canal was cut in the neighborhood of London which passes over a very hilly tract of land, and in the summer months there is great difficulty in obtaining a sufficient supply of water for the upper level. It is true the canal passes very near some copious brooks and streams, which with little expense or trouble might have been made available to supply every deficiency twenty times over; but from some circumstances the proprietors of the canal were not permitted to take advantage of these facilities, and as the rain-water they were enabled to collect from the hills was inadequate, they were under the necessity of resorting to the bowels of the earth to supply the deficiency. For this purpose, a large hole was bored down at the side of the canal, to a depth of two or three hundred feet, to what was understood to be the main spring; the water speedily rose and flowed over the surface; however, it was soon discovered, that the quantity obtained by this means was so very small as to be of no practical utility: a well of large dimensions was then sunk down about 80 feet, the boring still continuing to the original depth; pumps were fixed, and machinery worked by horses; the supply of water by this means was increased tenfold, but still was inadequate for the purpose required. We were then employed to erect a steam-engine with suitable pumps, &c., and the well was sunk to double the original depth; a much more copious supply was now obtained, and the navigation thereby greatly assisted; but after all, the expenses attending these works, and the pumping up the water from such a depth, and that too still inadequate in quantity, are evils of such a serious magnitude, that these joined to other circumstances attending this property, will probably before long cause the whole of the concern to be abandoned.

We could add many other instances of the total failure of what is called the simple boring system; of works begun and never finished to any useful purpose; of others pertinaciously carried on for four or five years, until the patience and the funds of the parties were alike exhausted; but we think enough has been stated above to prove to your satisfaction, how very uncertain has been this method of obtaining water. We think it right, however, to guard against the impression that boring for water is a bad system; on the contrary, allow us to repeat that we think most highly of it; but then only under proper management, and as a useful auxiliary to the sinking of capacious wells.

With respect to the project generally, of forming a regular establishment for the purpose of supplying water to the various towns of France, we have to remark, that there can exist no physical impediment to the accomplishment of the plan; there is no question but every town in France might be made to enjoy the same inestimable advantages possessed by the inhabitants of London and other towns of England; that is to say, a constant, abundant, and an economical supply of good water, for all purposes of domestic and manufacturing use; but of the three modes by which this can be accomplished, the one by boring or well-sinking is decidedly the most expensive, and the most uncertain in the final results.

SOME ACCOUNT OF SEVERAL SECTIONS THROUGH TAE PLASTIC CLAY FORMATION IN THE VICINITY OF LONDON. BY WILLIAM GRAVATT. F.R.S., M.INST.C.E.

TRING HILL, HERTS.

A boring for water for the Grand Junction Canal commenced at 25 feet below the summit level of the hill near Marsheroft Bridge.

Chalk	20 feet.	
Hard blue clay	30	
Blue stone	4.	At 54 feet the water rose to the top, and ran over 1300 cubic feet in 24 hours.
Hard blue clay	47	
	101 feet	—no more water than at 54 feet.

The boring discontinued in Nov. 1827.

A second boring in the same hill commenced 20 feet from the summit level.

Chalk	30 feet.	
Hard blue clay	34	
Blue stone	4.	Water rose up. The stone required punching before using the auger.
Blue clay	82	Strata of indurated clay at about every 4 feet, so hard as to require punching from 2 to 10 inches.
Black grit	10	
Blue clay	108	very hard.
	268 feet.	Boring discontinued—

no more water than at first. These two borings cost £145 and were 3 months in hand.

NORWOOD, NEAR STANDWELL.

A well 4 feet diameter sunk and bricked 280 feet through blue clay, into sand; the instant the sand was reached, the water rushed up to the top so fast as to endanger the workmen; it now stands within 8 feet of the surface of the canal, which is 86 feet above Trinity high water-mark.

BOKING AT BRENTFORD, SIX MILES FROM LONDON.

Brick earth	9 feet.	
Sandy gravel	7	
Loam	5	varies from 1 to 9 feet.
Sand and gravel	4	varies from 2 to 8. Contains water.
Blue clay	200	
	225 feet.	Boring discontinued—still in clay.

WOOLWICH SANDPITS.

Alluvium of various depths.

Rolled flints with sand	12 feet.	
Clay, striped brown and red, a few shells	6	water, merely drops.
Blue and brown clay, many shells	9	
Iron shot sand, with ocherous lumps	9	
Greenish sand, *clean*	8	
Greenish sand with flint pebbles	1	
Light ash-colored sand, perfectly clean	35	
Green sand, with green chalk	1	
Chalk	unknown.	

PLUMSTEAD COMMON.

Shafts for Chalk.

No. I. Alluvial gravel, and pure ash-colored sand	120 feet.
Chalk penetrated to	24
No water at	144
No. II. Alluvial Gravel	36

Stopped by the water.

No. III. At a small distance from this, stopped again by water at the same depth.

N. B. These three shafts were in the same field.

BOSTON HEATH, NEAR WOOLWICH.

A well sunk for water.

Gravel	65 feet.
Sandy beds	65
Chalk	70
	200

The water stands only five feet deep in this well; a trifling supply of water was found in the gravel.

LEWISHAM LOAM PIT HILL.

Alluvium various.

Striped sand, yellow, fine, and iron shot	10 feet.
Striped loam, and plastic clay, with thin seams of coaly matter	10
Yellow sand	3
Lead-colored clay, with casts of leaves	2
Brownish clay with cytherea	6
Three thin beds of clay, the upper and lower with cytherea, and the middle with oysters.	3
Loam and sand	4
Iron shot sand, with flint pebbles	12
Coarse green sand	5
Clean ash colored sand	35
Green sand	1
	91

Chalk with nodules of flint unknown.

REDRIFF DRIFT SHAFT.

	Ft.	In.
Vegetable mould	6	9
Brown clay	0	9
Gravel with water	26	8
Blue clay	3	0
Loam	5	1
Blue clay, with bivalve shells	3	9
Gravel and calcareous rock	7	6
Light blue soil with pyrites	4	6
Green sand	1	9
Leafy clay	8	4
	68	1

A pipe sunk by Mr. Turner 95 feet deep, near Bermondsey new church;—when they reached 80 feet, the rod sunk down 15 feet at once; after pumping out several tons of green mud, the water rose to within 25 feet of the top; it rises and falls about three feet with the tide; the water is quite clear and tasteless. At a place not 500 yards from this, they sunk a pipe 190 feet with very little success, the water being out of reach of a pump, and appearing bad.

SOME ACCOUNTS OF BORINGS FOR WATEH IN LONDON AND ITS VICINITY. BY MR. JOHN DONKIN, M.INST.C.E.

PARTICULARS OF A WELL SUNK AT THE EXCISE OFFICE, IN BROAD-STREET LONDON.

In the first place, after excavating the upper stratum of gravel and loose soil, four cast-iron curbs were sunk, each 6 feet long; the lowest of these entered the clay about 3 feet; the digging was then continued through the clay to the depth of 140 feet, and a curb of brickwork within the iron curb was sunk the whole depth in the ordinary way, the iron curb serving merely to support the upper stratum, and to prevent the land water getting into the well. Boring was then resorted to, to the depth of about 20 feet, when the water appeared, and rose to within 60 feet of the top of the well; a copper pipe was then driven through the last-mentioned 20 feet, to keep the passage open for the supply.

WELLS SUNK AT MESSRS. BRANDRAM'S VITRIOL AND WHITE LEAD WORKS, LOWER ROAD, DEPTFORD.

The wood and brick curbing was sunk barely 30 feet; the bricks were laid in Roman cement to keep out the water from the land springs; the well was then bored to the depth of about 180 feet into a bed of chalk, from which the soft water rises and flows to within 9 feet of the top of the well, through wrought iron tubes riveted together. The strata are chiefly composed of yellow and green sand and gravel, like those found at the tunnel under the Thames.

ACCOUNT OF BORINGS MADE NEAR LONDON, WHERE THE WATERS RISES ABOVE THE SURFACE OF THE LAND.

In Mr. Wilmot's garden at Isleworth, a boring was executed to the depth of 327 feet. The blue clay was found to exist from about 24 feet below the ground level, with little variation of color, to the depth of 240 feet: it is then of a lightish red, and afterwards of a darker color very much variegated. At the depth of 308 feet it is blackish, and at 310 feet very black; at 311 feet it becemes yellow for some depth; then light green, followed by dark green, out of which the water rises, being a stratum of about 10 feet thick.

All the specimens, with the exception of the yellow, appeared to be clay; the yellow had a sandy appearance. The cast-iron pipe is sunk 327 feet, and is 2½ inches diameter. The water rises about 10 feet above the ground, and the well supplies eight gallons per minute. The land water here stands about 16 feet below the ground.

Lord Cassilis* has also had a boring executed in his grounds at Isleworth, to the depth of 290 feet; the quantity it supplies is about 30 gallons per minute, and its water rises about 30 feet above the level of the surface.

* Now Marquess of Ailsa.

THE

BUILDER'S MANUAL.

(Continued from page 138.)

The cementing quality of lime seems to arise from its chemical combination with the substances with which it is mixed.—First of all it unites with a certain proportion of water, forming a hydrate of lime, which appears to have a chemieal attraction for silica, that is to say, the sand with which it is mixed. After exposure to the atmosphere for a short time, it abstracts and applies a portion of carbonic acid, which greatly increases its hardness, and on this account all old mortars are remarkable for their cohesion and strength, frequently becoming stronger than the stones they unite. Sir Humphrey Davy, speaking of cement, says, "The cements which act by combining with carbonic acid, or the common mortars, are made by mixing together slaked lime and sand. These mortars at first solidify as hydrates, and are slowly converted into carbonate of lime, by the action of the carbonic acid of the air. Mr. Tennant found that a mortar of this kind in three years and a quarter, had regained 63 per cent. of the quantity of carbonic acid which constitutes the definite proportion in carbonate of lime." But there are two kinds of cement used in building: that in which lime forms a prominent combination with water, and this is called a water cement; and that which combines with carbonic acid, which is called a mortar: this distinction is a very important one; one kind has the property of setting under water, the other has not.

Sand.

Sand is a very important ingredient in cements, and too much pains cannot be taken to obtain it pure. River sand should

be always preferred to pit sand, for it is less likely to be mixed with clayey or other substances, which greatly injure the indurating property of the cement. But wherever the sand may be obtained, it should be well washed, and this is especially nenessary if taken from the sea; for the salt with which it is combined, having strong hygrometric properties, would prevent the cement from drying. This effect we remember to have frequently observed in a little seaport town, where beach-sand had been used by the builders, without sufficient washing.

Mortar.

Mortar is made of lime and sand, thoroughly mixed together, and brought into the consistency of a paste, by the addition of water. Different proportions of these substances are used by builders, and this must necessarily be the case, for a larger or smaller quantity of sand must be added in proportion to the quality of the lime. A good lime will take more sand than a bad one, and the value of the cement may, in a great measure, be judged of by the quantity of sand it contains. Builders are accustomed, for instance, to use more sand with stone-lime than with chalk-lime; not that there is in general much difference between the two, when first burnt, but because the quality of the chalk-lime is speedily injured by a very rapid absorption of carbonic acid. With one hundred and fifty pecks, that is, thirty-seven and a half striked bushels of chalk-lime, the workman mixes two loads of sand, each load consisting of thirty striked bushels; but twenty bushels of stone-lime will frequently bear two loads and a half of sand. It is estimated that the mortar produced by either of these proportions, will do a rod of brickwork, that is, two hundred and seventy-two and a quarter square feet, superficial measure, a brick and a half thick, that is, about fourteen inches. According to the experiments of Dr. Higgins, a proportion of one peck of lime to seven of sand, makes the best mortar.

When mortar is to be used in a situation where it will dry quickly, it should be made with as little water as possible, but it is better that the mortar should dry gradually and slowly, as it then becomes more indurated. It is stated by some writers that mortar is injured by keeping, and under one condition, exposure to the air, it is; but, if excluded from the air, it is rather benefited than injured. Pliny states, that the Roman builders were prohibited by law from using a mortar that was less than three years old; and attributes the stability of all their large buildings to this circumstance. But when old mortar is used, it should be well beaten up before it is employed. The reader must not, however, suppose that these remarks justify the exposure of mortar to the air for a considerable time before it is used, a practice very common, but highly improper. This practice probably arose from the difficulty which workmen sometimes find in slaking the lime, in consquence of its being insufficiently burnt, or containing a large portion of argilaceous matter. But of all other things, it is important to use good lime, and to soak the bricks which are to be bedded, before they are laid; for, if the bricks are dry, they imbibe the moisture of the cement, and destroy its quality. There are two things which cause mortar and cements generally to crack, too small a quantity of sand and a too rapid exhalation of the water. There must always be a contraction, but it is least in those mortars which contain the greatest proportion of sand; for it is the moistened lime which contracts during the process of drying. All mortars may, for a time, be affected by atmospheric changes, and especially by alternate wetting and freezing; but this is the most remarkable in those which are liable to crack. A mortar which sets without cracking will always stand afterwards.

Dr. Higgins, to whom we are much indebted for his experiments upon cements, invented one which he speaks of as admirably adapted for both internal and external work; and becomes as hard as Portland stone when dry. "Take," he says, "fifty-six pounds of coarse sand, and forty-two pounds of fine sand; mix them on a large plank of hard wood, placed horizontally; then spread the sand so that it may stand at the height of six inches, with a flat surface, on the plank; wet it with the cementing liquor; to the wetted sand add fourteen pounds of the purified lime, in several successive portions, mixing and beating them together; then add fourteen pounds of bone-ash in successive portions,

mixing and beating all together." Whatever may be the quality of this cement, it is not likely ever to come into general use, as it would be more expensive, and give more trouble in preparation, than many others which are now found to answer the builder's purpose. This, however, was proposed as a water-cement. Mortar is evidently unfit to be used in any situation where the force of water is to be resisted; for although it is said that mortar composed of lime and sand, in the proportion of one and seven, will not suffer from water, yet, as this composition is seldom, if ever, obtained, it would be folly to risk the security of a building by its use.

The insufficiency of mortar for all those works, the whole or part of which are under the water, induced the scientific builder and chemists to seek a substitute. Many compositions have been recommended, and several of them have been found to answer the purpose. There is one substance, however, Roman cement, which, above all others, is extremely useful for a number of purposes, and will require our attention; and if our remarks should occupy a space which may appear to have no proportion to the length of the other parts of the volume, the importance of the subject will be a sufficient excuse.

Roman Cement.

Roman cement was accidentally discovered in the year 1796, by Mr. Parker, whose attention was attracted, when walking beneath the cliffs of blue clay, on the shores of the island of Sheppy, by the uniform appearance of the masses of stone which were strewed here and there upon the beach, and were seen projecting from the cliffs. As a mere matter of curiosity, he collected two or three fragments, and happened afterwards to throw one of these pieces in the fire. After it had been exposed for some time to the fire, it fell upon the hearth, and was there found by Mr. Parker, who was induced to make some experiments upon its cohesive properties, which led him to the discovery of its value, as a strong and durable cement. He then immediately applied to the Government of the day, for a patent, which was granted to him for fourteen years; and having secured to himself the right of manufacture, realized an ample fortune.

So great has been the recent demand for cement stone, that its quantity has been much diminished, and other substances have been substituted to so great an extent, that the cement now used is much inferior to that originally manufactured by Mr. Parker.—So small is the quantity obtained on the Sheppy coast, that the manufacturer is scarcely repaid for the cost of a search. The natural physical causes which are constantly active, have a tendency to increase the quantity upon the beach which surrounds this interesting island; but all natural agents act in a slow and progressive manner, so as to afford a very inadequate supply for the demand which is now made for this material. The masses once abundantly strewed over the shores of the island of Sheppy have been long since removed by the cement manufacturers, and the supply which is now obtained from this spot depends upon the quantity of the cliff that may be thrown down by the undermining influence of land-springs, or by other cause. At the base of the cliffs which surrounds this island may be seen, here and there, extensive land springs, which weaken the foundation of the clay, and frequently cause masses of large extent to fall upon the beach. This cause is aided by the storms which, during the winter season, frequently blow upon its shore, and, either by the force of the waves or by the subsequent drying of the saturated mass of clay, weakens its cohesion, and produces the same effect. The falling of the cliffs produced by these and other means, furnishes a small quantity of cement stone, but a quantity altogether inadequate for the supply of the demand. But as far as observation extends, it appears that these nodular stones are found in all the deposits of London or blue clay. This stratum is found in Harwich, and other places, as well as at Sheppy; and the attention of the manufacturer was consequently directed to them, for a supply of the material. But it has been stated, and experiment seems to justify the assertion, that the Sheppy stone yields a much better cement than that which is obtained from other places: the cause cannot be readily determined; but so great a value is placed upon the former, that some persons have actually excavated for the purpose of obtaining it. But the principal part of that now used by manufacturers is obtained from Harwich; and not less than from

thirty to forty tons weight are annually collected in this place. The engineer and architect still prefer the Sheppy cement, which has a much lighter color than that made from the Harwich stone, but is far more expensive. The manufacturer, however, now so frequently intermixes other ingredients with the Harwich cement, to give it the same appearance as the Sheppy, that it is almost impossible to determine the quality by the color. Limestones, found in other places, have been substituted for the Sheppy nodules; all of which, excepting that which is found in small quantities in the marshes of Essex, near Steeple, are much inferior to it.

The manufacture of cement is extremely simple, although some experience is necessary, as the character of the cement will depend as much upon the manner in which it is made, as upon the property of the stone. After the stone has been broken into small pieces it is thrown into a kiln, with a proportion of small coal, to be burnt. A strong red heat must now be supported throughout, and considerable skill, or rather experience, is required to accomplish this purpose, for the relative degrees of hardness in the several pieces, and other causes, tend to give them an unequal temperature and to prevent perfect calcination. After the stone has remained from thirty to forty hours in the kiln, in which time it is usually perfectly burnt, it is taken to the mill, and being immediately ground to powder is packed in casks and sent into market. Promptness in all the processes which follow burning is absolutely necessary, for the contact of the air impairs the adhesive power of the cement. Hence it is that builders who study the character of their materials invariably prefer the cement which is made in large manufactories; a ready sale generally securing, them from the use of an old cement. Good cement perfectly burnt has a light-brown color, and has very little weight; but if imperfectly burnt it is heavy and has a dark color: when the stone is burnt overmuch, small black carbonized particles may be observed. It may be necessary to state that the cement should always be reduced to as fine a powder as possible; and to accomplish this an attempt was made some time since to sift it, but its exposure to the air was found to injure its properties as cement. As a test to the value of a cement the experimenter may mix with it a quantity equal to two-thirds of clean, well washed, and dried sand, and should it then have a strong cohesive power he may depend upon its qualities; but as soon as the two ingredients are mixed and moistened, the cement should be used, or it will either fail to set or to possess an adequate adhesive power. These suggestions, if carried out, will be found of great importance in the art of building, and particularly in those instances where great stability is required. The builder frequently attributes to the cement that which depends upon its own injudicious use or exposure of the material; and even bad cement may be made tolerably effective for ordinary purposes, if it be little exposed to the atmosphere, and be used immediately after its mixture.

Roman cement should never be used in any situation where there is the slighest chance of warping or spring, for as it does not possess any elastic force it is sure to break way. For covering walls when used as a stucco it is well suited, but the bricks should be damped previous to its application, or they will absorb its moisture and give it a porous structure. But stucco will not bind upon a bed of stucco, and it is therefore necessary that it should be applied in one coat; for, as good cement will set in about twenty minutes, a second bed cannot be applied at any subsequent period without endangering the stability of the work, for one coat is almost sure to separate from the other.

To ascertain the relative value of any number of cements, mix them with certain proportions of sand, and that which is the hardest with the largest proportion is the best. As a collateral proof the specimens may be kept for a few days, and it will be found that a quantity of bloom formed upon their surfaces will have some relation to their qualities. Good cement, will always be raised to a great temperature when mixed, and those which are not may be considered worthless. There are some cements that harden very quickly, and yet are of very bad quality, and will in the course of a few hours become quite soft. These facts are well worthy the attention of the workman or the builder, for they will not only enable him to ascertain which is a good and which a bad material, but also to use the material

he may choose, in the most advantageous manner.

Chemists and others who have investigated the properties of hydraulic limes are not by any means agreed as to the cause of the cementitious quality. Saussure was of opinion that their peculiar properties were derived, from the presence of silex and alumina in certain proportions; Descotils attributes them to the presence of a large proportion of silex, and Bergman and Guyton to a small proportion of manganese.

The Roman is the most valuable of all water-cements, as well for the ease with which it may be used, as its hardness and durability. As it sets in about fifteen minutes, the workman cannot mix more than a small quantity at once. Experience will soon teach how much can be worked in a certain time: an appropriate quantity must be taken upon a clean board and something more than an equal quantity of very clean and dry river sand. When the lime and sand are thoroughly mixed, as much clean water as is necessary to form them into a paste should be added. The workman should then immediately use it, and after it has been once applied, it should not be in any way disturbed. Forty bushels of cement, with its apropriate quantity of sand, will do a rod of brick-work. Good cement will take two parts of sand, and that cannot be called good which will not take one and a half.

When cement is used for coating or lining walls it must have as much sand as possible, so as not be too stiff to work. It must also be always worked in one coat, and the surface to which it is applied should be clean and well wetted. Cement when thus used is called stucco, and should be laid on three-quarters of an inch in thickness. A bushel of cement with its proper proportion of sand will cover a surface of two square yards.

Cement is also used for casting ornaments, for which purpose it answers exceedingly well. Gothic work is sometimes finished in this way, but, although it may be desirable in some instances, it is generally better to use stone where very ornamented work is to be introduced.

There are several other kinds of cemen which are occasionally employed by the bricklayer, but they are not of sufficient importance to be treated of in a work which can only give some of the most prominent facts in the art of building. But it may be asked, what was used before Parker's cement was discovered? This question leads us to make a few remarks upon two cements which were once extensively used in this country, Puzzolana and Tarras, but are now scarcely ever employed.

Puzzolana.

Puzzolana is a volcanic substance, consis ing, according to Bergman's analysis, of from fifty-five to sixty per cent. of silica, from nineteen to twenty of alumina, five of lime, and twenty of iron. The Romans were accustomed to mix this substance wi h lime in the manufacture of water-cements, and the same method was a long time adopted in England. The hardening of the mortar is supposed to arise from the union of the oxygen of the water with the iron.

Tarras.

Tarras or Tras is a substance found at Andernach, in the department of the Rhine, and, according to Bergman, differs but little from Puzzolana in composition. Tarras mortar is well suited for all those situations in which it is constantly exposed to wate , but it cannot resist the action of alternate wet and dry, and indeed is never so firm when it sets in exposure to air as under the water. The principal objection to the use of this mortar was its expense, and consequently the Dutch attempted to supply its place by the union of substances found in their own country, and succeeded so well that a large quantity was imported into this country, and extensively used. There are two proportions which have been adopted as the best for Tarras mortar: in one kind a measure of quick lime is mixed with a measure of Tarras, and being thoroughly mixed are brought into the consistence of paste by the addition of water, as little water being used as possible; in the other, one measure of Tarras is mixed with two measures of slaked lime and three of sand,—this is almost as good a cement and much cheaper than the former.

THE METHODS OF LAYING BRICKS.

The strength of walls and piers of brick-work depends as much on the manner in which the courses are placed, as on the quality of the materials employed in con-

struction; for, however good the bricks may be, if they are not so placed as to strengthen one another, and mutually confine each other to their several situations, the work cannot have the requisite stability. If the perpendicular joints in the several courses are too nearly over each other, the work is liable to crack in a vertical direction, and if the bricks, forming the outer and inward face of the wall do not bind together, the work will bulge, and the wall must at last fall to pieces by its own weight. It is therefore important for us to determine the best method of laying bricks, and we shall endeavor to describe the means adopted by builders to prevent the separation of the work, and give a solid bearing to every part.

Those bricks which are so placed that their length is in the direction of the wall, are called stretchers; and those which are placed with their length across the wall, are called headers.

The two principal methods of bricklaying are severally called English and Flemish bond. English bond is generally preferred by builders as being decidedly the strongest, though it has not so neat and regular an appearance as Flemish. English bond consists of alternate courses of headers and stretchers; thus, one course is formed with headers, that is, with bricks crossing the wall; the next with stretchers, that is, with bricks having their length in the same direction as that of the wall: the headers serve to bind the wall together in a longitudinal direction, and the stretchers prevent the wall from separating crossways.

Flemish bond consists in placing a header and a stretcher alternately throughout every course. This method of bricklaying is very much adopted, on account of the regular appearance it gives to the face of the work, but in order to have this result, a header must always be placed over the middle of the stretcher below it. The Flemish bond, though inferior in many respects to the English, is very generally used, and an inferior brick is placed in the interior of the wall, and those which form the face, are picked or chosen, that the work may have a uniform color. The greatest fault in this method of bricklaying is, that by making a putty joint on the face, the interior bricks do not range level with the exterior ones, and this prevents the builder from connecting his work by headers extending through the whole thickness of the wall.

THE CARPENTER.

A CARPENTER is a workman who executes that combination of timbers which may be considered, in connexion with the bricklayer's work, as the frame or skeleton of a building. There is, however, this difference between the objects of the one and of the other; the bricklayer has only to consider the downward pressure or force of gravity, and the forces which may be exerted, tending to destroy the perpendicular; the carpenter must also study the relative disposition of parts, so as to alleviate as much as possible the strains which may be exerted upon the building.

Carpenter's work is distinguished from that of the joiner's; for while the one has regard to the substantial parts of an edifice, those which give solidity and strength, such as the construction of roofs, floors, and partitions, the other consists in providing for the ornamental and convenient. A carpenter should be well acquainted with the strength and character of the materials he uses, and especially as he employs them in great masses. He should also be careful not to overload a building, or to employ larger timbers than are absolutely necessary; for, if there were no danger in so doing, economy would dictate the necessity of this care. It is then important that the carpenter should be able to ascertain the dimensions required for the several parts of a building, so as to produce a maximum of strength, without overloading the walls or his own work. and at the same time, to avoid the danger which must result from a scantiness of material. There are then two things to be considered, the strength of the materials, and the stress to which they are subject in certain situations. A timber, or framing, may be strained in various ways, but of these we shall speak presently; our first object is to describe the materials themselves, referring particularly to those woods which are most commonly used.

Oak.

There are many species of oak, but that known am ng botanists, as the "Quercus robur," is most esteemed. It may, however, be necessary to remark in relation to this, as well as all other kinds of timber

trees, that the character of the wood must greatly depend upon the soil in which it grew, and the degree of attention it received from the cultivator. The oak of Sussex is most esteemed by builders, but, whether the preference is dictated by experience or prejudice, we are unable to state: but we are not acquainted with any series of experiments that warrants the choice, and it is not fit that practice should be regulated by unproved statements.

A Norway oak, called clapboad, is frequently brought to London; and also one that is grown in Germany, called Dutch wainscot, being imported from Holland, to which country it is brought in floats down the Rhine. Both these woods have been extensively used in this country, and it is probable that the wainscot will be still employed for many purposes, for, though it is softer and the grain more open than the English oak, it is also less liable to warp.

Oak is the most durable of all woods, and surpasses them in strength and stability. Vitruvius says, that it has an eternal duration, and when we see the beautiful specimens which have remained untouched by time, in our oldest buildings, though all other materials are crumbling around them, we feel an inclination to assent to his opinion. It is, however, only the close grained varieties that deserve this character; and it is no small addition to the professional skill of the architects of past ages, that by the choice of the best materials, they gave a perpetuity to their works, which few, if any, of the present day can rationally expect.

Oak may be used in all those places where strength is required, and its flexibility does not present an objection. For sleepers, wall-plates, ties, king-posts, and other such purposes, it should be used more frequently than it is. But its chief application is for ship-timber, and some thousand loads are annually used in our Dock-yards. This remark suggests the propriety of using it in all those places which are much exposed to the variation of weather.

Fir.

There are many species of fir, all of which are more or less used in building; but there are three sorts in particular that require our attention, being more used than any others: these are the Pinus Sylvestris, or yellow fir; the Pinus Abies, or spruce fir; and the Pinus Resinosus, or pitch pine.

The red or yellow fir is a native of Scotland, and the Northern counties of Europe. This tree is more abundant than all others in the boundless forests of Norway and Sweden. It grows to an immense height, very straight, and with few branches. The fir timber of Norway is brought into this country under the name of masts and spars; those which are eighteen inches or more in diameter are called masts, and are frequently eighty feet in length; others are called spars. In several parts of Scotland the yellow fir is grown, and attains a great height.

The yellow fir or deal is much used in building, and is a very durable wood; according to some authors, as much so as oak. But whether this be the case or not, it has many qualities which render it exceedingly useful to both the carpenter and joiner. It is light and easily worked, yet stiff, and capable of bearing great weights. It is commonly employed for framing, girders, joists, and rafters; for joiner's work also it is almost universally used.

White fir is also a native of the north of Europe; and is especially abundant in Norway and Denmark, and is sometimes called the Norway spruce. The larger quantity of that which is brought into this country, is imported from Christiana in deals and planks. Deals are formed by cutting the fir tree into thicknesses of generally about three inches, the width being about nine. As fir is exceedingly liable to shrink, it is very necessary that it should be well seasoned, and this is especially the case with white fir, which should never be used in those places which are exposed to atmospheric changes. We are informed by travellers, that the tree is first cut into three lengths of about twelve feet long, each of which are divided into three deals.

The pitch pine, which is a native of Canada, is sometimes employed by the carpenter, but not so frequently as those kinds we have already mentioned. This wood is much heavier than either of those we have already described, but it is less durable. Its name has been derived from the circumstance of its containing a large quantity of resin, which makes it very unfit for building purposes, and very difficult to work.

Larch.

There are three species of Larch; one is a native of Germany and the neighboring countries, the other two are Americans. The European species (Pinus larix,) sometimes grows to a great height, and contains a large quantity of timber; one which was cut at Blair Athall in 1817, is said to have contained 252 cubic feet of timber; this, however, was a tree of remarkable size.

Mr. Tredgold, in his most interesting and useful work on Carpentry, has made some appropriate remarks upon the character of this wood. "It is extremely durable in all situations, failing only where any other kind would fail: for this valuable property it has been celebrated from the time of Vitruvius, who regrets that it could not be easily transported to Rome, where such a wood would have been so valuable. It appears, however, that this was sometimes done, for we are told that Tiberius caused the Naumachiarian bridge, constructed by Augustus, and afterwards burnt, to be rebuilt of larch planks, procured from Rhœtia. Among these was a trunk 120 feet in length, which excited the admiration of all Rome. The celebrated Scamozzi also extols the larch for every purpose of building, and it has not been found less valuable when grown in proper soils and situations in Britain. In posts and other situations, where it is exposed to damp and the weather, it is found to be very durable. In countries where larch abounds, it is often used to cover buildings, which, when first done, are the natural color of the wood, but in two or three years they become covered with resin, and as black as charcoal; the resin forms a kind of impenetrable varnish, which effectually resists the weather. Larch is not attacked by common worms, and does not inflame readily.

The larch is useful for every purpose of building, whether external or internal; it makes excellent ship-timber, masts, boats, posts, rails, and furniture. It is peculiarly adapted for flooring-boards in situations where there is much wear, and for staircases; in the latter, its fine color, when rubbed with il, is much preferable to that of the black oaken staircases to be seen in some old mansions. That we may not give an erroneous estimate of the value of the larch as applicable to building purposes, it is necessary to state that it is worked with more difficulty than fir, and is even more liable to warp, unless it be perfectly seasoned.

Beech.

The beech (Fagus sylvatica,) is not much used in building, on account of the very rapid decay it undergoes whenever it is affected by dampness. It grows in our own, as well as in most European countries; but it prefers a dry soil, and, in England, flourishes most in chalk districts.—There are two kinds of beech-wood; one is called the brown or black beech, the other the white; it is, however, generally supposed that the difference is due to the character of the soil, and not to any specific distinction. Beech is a hard, fine-grained wood, and has been much used for the commoner kinds of household furniture.—It may appear singular that it should be well adapted for piles, provided it is constantly immersed in water; but damp destroys it very readily. Nor is this the only objection to its being used in building; for even the best, which is the white, is soon injured by worms, whether in a dry or damp situation.

Ash.

There are several species of ash, but the one which is most common in Europe, called by botanists the Fraxinus excelsior, is the most valuable. The tree sometimes grows to an immense size; but its mean diameter is said not to exceed twenty-three inches. The texture of the wood is alternately compact and porous, and presents a veined appearance, the veins being darker than those of the oak. On account of its great flexibility, and want of durability, it is not ever applied for framing or for timbers. From the experiments which have been made, it appears that it is tougher and stronger than oak, and, were it not for its great flexibility, might be, in many instances, advantageously employed by the carpenter. It is not, however, without a use in the arts, being exceedingly well adapted for many parts of machines and carriages.

Elm.

Five species of elm are found in this country; but the wych elm (Ulmus campestris,) and the smooth-barked elm (Ulmus glabra,) are most valuable. Elm decays

rapidly when exposed to variations of weather; but is durable when kept constantly dry, or constantly under water. The piles upon which Old London Bridge was erected, were elm, and their soundness, after an exposure to water for some centuries, proves the truth of one of these statements. It is a porous and generally coarse cross-grained wood; and, on this account, should never be used in any piece of framing where a strain is to be supported. But, in addition to this, it is liable to shrink both in breadth and length, though it is not readily split. It is by no means an important wood to the builder; but a large quantity is used in this country. For many hydraulic works it is very useful; some parts of ships are constructed of it; and it is generally employed for coffins, piles, and wet planks. The wood of the wych elm is preferred to all others.

Chesnut.

The chesnut (Fagus castanea,) is one of the most long-lived of all European trees. It is a native of many parts of Europe, and was at one time very common in England, yielding the principal timber at the time. The roof of King's College, Cambridge, is made of chesnut, which is one instance of its durability in a dry state. It is also well adapted for water-pipes, casks, and other vessels intended to hold fluids. When thoroughly seasoned it will neither shrink nor swell, and may be applied for all those purposes for which oak is used, and in some instances is more useful. The wood is hard, and, when young, tough and flexible. It is not always easy to distinguish between oak and chesnut, for they much resemble each other in color and in grain; but they may be known, says Sir Humphrey Davy, "by this circumstance, that the pores in the alburnum of the oak are much larger and more thickly set, and are easily distinguished; while the pores in the chesnut require glasses, to be seen distinctly." The wood of old trees is generally brittle, and should never be used in those situations where it will be subject to a considerable strain It has also been stated, that when chesnut is shut out from the access of air, it quickly decays. It is much to be regretted that the culture of this tree, at once ornamental and useful, should be so much neglected in England. In some instances it has been known to live from eight hundred to a thousand years; and its full and beautiful foliage might induce the land proprietor to propagate it, even if he should be uninfluenced by its usefulness in the art of building.

Walnut.

The common walnut (Inglans regia,) is a native of Persia; but was once cultivated in this country as much for its wood as its fruit. It is a greyish-brown wood, with a fine grain; but, if it were not scarce, and could be obtained by the builder for the same money as the woods now employed by him, it would be very unfit, on account of its flexibility and aptness to split, for all those situations where a weight is to be sustained; though it was sometimes used for this purpose in former times. It is now chiefly used for gun-stocks, handles to steel instruments, and for furniture. It is less liable to be attacked by worms than perhaps any other wood, excepting cedar.—For some building purposes, particularly for some joiner's work, it might be advantageously employed, could the supply be sufficient.

Mahogany.

This wood is the produce of a tree called the Swietenia mahogoni It is much used by cabinet-makers, and frequently by joiners for doors, hand-rails, tops of counters, and other ornamental work. The tree is a native of the West India Isles, and of the Bay of Honduras in America. On account of its costliness, it cannot be extensively used in this country by the carpenter, though its qualities are such as would make it otherwise desirable. The Spanish mahogany, or that which grows in the West Indies, is most esteemed, and is imported in lengths of about ten feet, and from twenty to twenty-six feet square.

Teak Wood.

Teak wood, or Indian oak, is obtained from the Coromandel coast. It is a light and durable wood, easily worked, and equal if not superior to oak in strength and stiffness. It is chiefly used for ship-building; a purpose for which it is well adapted, being of an oily nature, and yielding good tar.

Poplar.

Several kinds of Poplar grow in Eng-

land, but none of them are frequently employed by builders. The wood has a beautifully clean grain; it is light, though not very strong; is easily worked; and may be sometimes used for flooring in those situations where there cannot be much wear.

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The woods we have described are the most important of those used by the carpenter and joiner. To distinguish the one from the other, the reader must accustom himself to examine specimens carefully; for it is impossible, by any description, to give him a capability of doing so. Our object has been to relate the characters and properties of the several kinds of timber, as deduced from the experiments which have been made by practical and scientific men. There is one thing, we think, that will particularly strike the reader's attention, and should be constantly borne in mind: the same wood is not equally useful in different circumstances; and when we discover that it possesses durability in one situation, it by no means follows that it will have the same property in another. A wood may be admirably suited for floors, but it may be altogether unsuited for timbers, and all situations where great weights are to be sustained.

DECAY OF WOOD.

Allusion has been frequently made in the preceding remarks to the fact, that wood is, under some circumstances, susceptible of decay. Some woods decay much more rapidly than others; but they will all, in some situations, lose their fibrous texture, and, with it, their properties. But all circumstances are not equally favorable to decay; for it will be evident that there must be some arrangement of causes to produce this effect To ascertain the causes which act upon woods, and effect their destruction, is an important object both to the builder and to the public; for, untill this has been done, we cannot ever expect to ascertain any general principle that may guide us in our endeavor to avoid those circumstances which have a tendency to encourage the destruction, or to propose a remedy for the evil. The ravages which are constantly made upon all our works of art, give a character of insecurity to our labors; for the things which men accomplish with great perseverance and difficulty, in a length of time, are, in a few years, destroyed by invisible agents. In studying the decay of wood, there are three things that demand our attention, the causes, the circumstances under which those causes are most active, and the means by which they may be destroyed, or their effects in some degree neutralized.

CAUSE OF THE DECAY OF TIMBER.

All vegetable as well as animal substances when deprived of life are subject to decay. From a very early period attempts have been made to prevent this decomposition; and in some degree these attempts have been successful, more especially with animal bodies. The Egyptians were acquainted with so perfect a means of embalming animal substances, that the bodies of men and animals prepared by its earliest inhabitants have combated for centuries the influence of time, and have been found in a perfect state by our contemporaries. This being effected, it is reasonable to hope that some means may yet be provided that shall arrest the destruction of vegetable substances. It is not to be expected that it will ever be possible to give a perpetuity to a particular form of substance, but it is possible to remove in part the cause, and thus to give a lengthened continuance to one particular constitution of elementary principles.

If the trunk or branch of a tree be cut horizontally it will be seen that it consists of a series of concentric layers, differing from each other in color and tenacity. In distinct genera or species of trees these layers present very different appearances, but in all cases the outer rings are more porous and softer than the interior. Wood is essentially made up of vessels and cells, and the only solid parts are those coats which form them. These vessels carry the sap which circulates through the tree, gives life and energy to existence, and is the cause of the formation of leaves, flowers and fruit. But when the tree is dead, and the sap is still in the wood, it becomes the cause of vegetable decomposition by the process of fermetation. Fourcroy, the celebrated chemist, says, there are five distinct species of vegetable fermentation, the saccharine, the coloring, the vinous, the ascetous, and the putrefactive. But we are but little

acquainted with the process by which the decomposition is carried on, but the effect is certain unless the albumen, one of the constituent proximate principles of vegetable matter, be disposed of, or be made to form with some other substance a compound not subject to the same process of decay. We are, it appears, indebted to Mr. Kyan for the discovery that albumen is the cause of putrefactive fermentation, and the subsequent decomposition of vegetable matter.

Circumstances favorable to Vegetable Decomposition.

Wood is not equally liable to decay under all circumstances. When thoroughly dried it is not so quickly decomposed as when in its green state, for in the latter condition it has in itself all the elements of destruction, and it is scarcely possible to prevent the effect if it be then used in building. But supposing the timber to be perfectly seasoned, it is more liable to decay under some circumstances than others. Timber is most durable when used in very dry places. Time, however, which decays all things but the thinking principle, affects the hardest wood even when employed in the most advantageous circumstances.—Yet timber which has been used in places where it receives no other moisture than that which it absorbs from the atmosphere has been known to last for seven or eight hundred years, though its elastic and cohesive powers are invariably injured.

When timber is constantly exposed to the action of water the decomposition effected will depend upon the nature and chemical composition of the substance. Vegetable matter is a compound, and an ingredient may be removed without destroying the whole. A portion of wood may be soluble in water, but other parts are not; so that after a definite period the continued action of water upon a piece of timber ceases, and if it can sustain the influence of this cause until that period, there is no termination to its endurance, except from those casualties which it might have been able to bear in its original state, but cannot after the removal of that portion of its substance soluble in water. Should a piece of timber that has been for a long time exposed to water be brought into the air and dried, it will become brittle and useless: this is usually the case with the timber taken from peat bogs, unless it should happen to be impregnated with some mineral substance that has stayed the action of the water.

When wood is alternately exposed to the influence of dryness and moisture it decays rapidly. It appears, from experiments that have been made, that after all the matter usually soluble in water has been removed, that a fresh maceration and contact of the air produces a state of matter in that which is left which renders it capable of solution. A piece of timber may then in this manner be more and more decomposed, until at last the whole mass is destroyed. The builder is sometimes compelled to use wood in places where it will be exposed to alternate dryness and moisture; fencing, weather boarding, and other works, are thus exposed. In all these cases he may anticipate the destructive process and provide against it. The wood used in such situations should be thoroughly seasoned and then painted or tarred, but, if it be painted when not thoroughly seasoned, the destruction will be hastened, for the evaporation of the contained vegetable juices is prevented.

There is one other circumstance to be considered, the influence of moisture associated with heat. Within certain limits the decomposition resulting from moisture increases with the temperature. The access of the air is not absolutely necessary to the carrying on of this process, but water is; and as it goes on, carbonic acid gas and hydrogen gas are given off. The woody fibre itself is not free from this decomposition, for, as the carbonaceous matter is abstracted by fermentation, it becomes more susceptible of this change. This statement is proved by the circumstance, that when quick lime is added to the moisture, the decomposition is accelerated, for it abstracts carbon. But the carbonate of lime produces no such effect: a practical lesson may be learnt from this fact; if timbers be bedded in mortar, decomposition must follow, for it is a long time before it can absorb sufficient carbonic acid to neutralize the effect, and the dampness which is collected by contact with the wet mortar increases the effect. When the wood and the lime are both in a dry state, no injury results, and it is well known that lime protects wood from worms.

When the destructive process first becomes visible it is by the swelling of the timber and the formation of a mould or fungus upon its surface. The fungus or cryptogamic plant rapidly increases, and

soon covers over the whole surface of a piece of timber, having a white, greyish-white, or brownish hue. When the seeds of destruction are thus once sown they cannot be readily eradicated; it need not therefore be a matter of surprise that many of the foreign woods used in this country have so little perpetuity when the reader is informed, that the heat of the hold of the vessel in which they are brought is sufficient of itself to cover them with mould or mildew. Heat and moisture may be considered the prominent causes of the rapid decomposition of vegetable subtances. When wood is completely and constantly covered with water this effect is not produced, and we have an example in the fact, that, although those parts of a vessel which are subject to an occasional moisture are liable to dry rot, yet those parts which are constantly beneath the water are not ever thus affected; and although the head of a pile, which may be now and then wetted by the casual rise of the tide, and is then dried again by the sun, may be decomposed, yet those parts which are always covered with water have been found in a solid state after centuries of emersion.

MEANS OF PREVENTING DECAY.

It cannot be thought a matter of small importance that we should have some means of preventing the decay to which wood appears to be so subject. Many experiments have been made under the hope of discovering a simple and effective process for the accomplishment of this purpose. Whenever there is a desirable object which seems to offer a prospect of fame or wealth to him who can secure it, there will always be many persons who, impelled by a sanguine disposition, or by bad motives, will propose schemes which are not founded on scientific principles, and frequently produce more harm than good. This we have frequently seen, and in a time like the present, when all men seem to be speculating for an existence, rather than seeking wealth and honorable independence by the legitimate exertion of intellect or skill, the public are peculiarly exposed to the impositions of the weak and of the crafty. Scarcely a month elapses but we hear some new specifics against the decay of timber, and yet when brought to the test of experiment they are found to be utterly useless. Some fortunate observation, some unexpected result, as the patentees inform us, led to the discovery; and as to the reason why this or that process should be effective, they neither know nor care. We do not, however, in these censures include the process proposed by Mr. Kyan, which we shall presently have occasion to explain.

Felling Timber.

Something may be done towards the prevention of decay by felling the timber at a proper season. A tree may be felled too soon or too late, in relation to its age, and to the period of the year. A tree may be so young that no part of it shall have the proper degree of hardness, and even its heart-wood may be no better than sap-wood; or a tree may be felled when it is so old that the wood, if not decayed, may have become brittle, losing all the elasticity of maturity. The timber grower is more likely to adopt from interested motives, the former of these errors, and fell his timber too young. His object is to obtain as much timber as possible, but a tree is not in its maturity when it ceases to grow, for after this period its fibres gain firmness and density. The time required to bring the several kinds of trees to maturity varies according to the nature of the tree and the situation in which it may be growing. Authors differ a century as to the age at which oak should be felled, some say one hundred, and others two hundred years; it must then be regulated according to circumstances. Although the oak of our own country is so valuable to the builder, yet it is to be feared that it is seldom allowed to attain its maturity, the grower being anxious to sell and the builder to buy; the one seeking to obtain its value himself, rather than leave it to posterity, the other to purchase at as low a price as possible, not caring for the character of the timber.

But it is also necessary that the timber-trees should be felled at a proper season of the year; that is to say, when their vessels are least loaded with those juices which are ready for the production of sap-wood and foliage. The timber of a tree felled in spring or in autumn, would be especially liable to decay; for it would contain the element of decomposition. Mid-summer and mid-winter are the proper times for cutting, as the vegetative powers are then expended.

There are some trees, the bark of which is valuable, as well as the timber; and as the best time for felling is not the best for stripping the bark, it is customary to perform

these labors at different periods. The oak-bark, for instance, is generally taken off in early spring. and the timber is felled as soon as the foliage is dead; and this method is found to be highly advantageous to the durability of the timber. The sap-wood is hardened, and all the available vegetable juices are expended in the production of foliage. Could this plan be adopted with other trees, it would be desirable; but the barks are not sufficiently valuable to pay the expense of stripping.

Seasoning Timber.

Supposing all these precautions to be taken in felling timber, it is still necessary to season it; that is, to adopt some means by which it may be dried, so as to throw off all the juices which are still associated with the fibres of the wood. As soon as the timber is felled, it should be removed to some dry place; and, being piled in such a manner as to admit a circulation of air, remain in log for some time, as it has a tendency to prevent warping. The next process is, to cut the timber into scantlings, and to place these upright in some dry situation, where there is a good current of air, avoiding the direct rays of the sun. The more gradually the process of seasoning is carried on, the better will be the wood for all the purposes of building. Mr. Tredgold says, "It is well known to chemists, that slow drying, will render many bodies less easy to dissolve; while rapid drying, on the contrary, renders the same bodies more soluble. Besides, all wood, in drying, loses a portion of its carbon, and the more in proportion as the temperature is higher. There is, in wood that has been properly seasoned, a toughness and elasticity which is not to be found in rapidly-dried wood. This is an eqident proof, that firm cohesion does not take place when the moisture is dissipated in a high heat. Also, seasoning by heat alone, produces a hard crust on the surface, which will scarcely ermit the moisture to evaporate from the internal part, and is very injurious to the wood.

"For the general purposes of carpentry, timber should not be used in less than two years after it is felled; and this is the least time that ought to be allowed for seasoning. For joiners' work it requires four years, unless other methods be used; but, for carpentry, natural seasoning should have the preference, unless the pressure of the air be removed."

Many artificial methods of seasoning timber have been proposed; and a brief notice of some of those which have been found most useful will be required.

Seasoning by a Vacuum.

All the vegetable and animal juices are kept in their particular vessels by the pressure of the atmosphere; remove that pressure, and the animal fluids could no longer be retained by the veins and arteries, and the vegetable fluids would exude and appear on the surface of the plant. Place a small piece of wood beneath the receiver of an air-pump, and exhaust the air, and in a short time the wood will be covered with drops of the liquid which can no longer be retained, as the atmospheric pressure is removed. Mr. Langton thought that this might be applied to the extraction of those vegetable juices in timber, known to be the cause of its decay. An arrangement was therefore adopted, by which large masses of timber might be enclosed in a vessel having such machinery as would be necessary to exhaust the air, heat being at the same time employed so as to vaporize the exuded juices. The vapor is conveyed away by pipes surrounded by cold water, and is condensed into a liquid, having a sweet taste. This process is deserving of more attention than has hitherto been given to it.

Water Seasoning.

It has been stated by various writers, that wood immersed in water for about a fortnight and then dried, is better suited for all the purposes of the joiner. There can be no doubt that immersion in water tends to neutralize the effect of the saccharine matter, by dilution or an almost absolute removal. This process has also the effect of rendering the wood less liable to crack and warp; but, if we judge by Duhamal's experiments, it injures the strength of the material, and should not, therefore, be adopted in any instance where the timber is to be employed by the carpenter. Evelyn recommends boards that are to be used for flooring, to be seasoned in this way: "Lay your boards," he says, "a fortnight in water (if running, the better, as at a mill-pond head); and then setting them upright in the sun and wind, so as it may pass freely through them, turn them daily; and thus treated, even newly-sawn boards will floor far better than those of a many years' dry

seasoning, as they call it." Timber intended for ship-building may be immersed in sea-water; but that which is to be used for houses ought to be placed in fresh water; for if timber, or any other building material, be impregnated with salt, it will ever be wet, for salt attracts moisture so readily, that it may be used approximately as a hygrometer. Plaster or mortar made with salt water, will always sweat with a moist atmosphere; and timber intended for the house-carpenter, if impregnated with salt, will always be damp, or covered with a crystalized efflorescence. Much injury, however, is sometimes done by not thoroughly immersing the timber; the carpenter should therefore be careful, when he employs this method of seasoning, that the timber is entirely covered with water, and that it be not exposed to its adtion for too long a time.

Seasoning by Smoking and Charring.

Authors who have written upon the seasoning of timber have spoken of the effects of smoke, and the carbonization of the surface. We have adopted the same arrangement, but it will be necessary to caution the reader against a misconception of a very inaccurate expression. Timber cannot be seasoned by either smoking or charring, but seasoned timbers may be made more capable of resisting the effects of certain situations by these processes. Should a piece of timber, containing the vegetable juice, be smoked or charred, it would be a means of accelerating decomposition; for preventing all means of evaporation, the common sources of protection, would become sources of destruction. But when timber is to be used in situations where it is liable to be attacked by worms, or to produce fungi, it may be desirable to smoke or to char it.

Seasoning by Boiling or Steaming.

Timber is sometimes seasoned by steaming or boiling, both of which means are frequently adopted by ship-builders. The strength of timber appears to be somewhat impaired by these processes, but it is generally less liable to shrink or crack. Duhamel states that he boiled a piece of wood, and then dried it upon a stove, but, in drying, it lost part of its substance, as well as the water contained; and upon a repetition, he found that it had lost still more of its weight. Four hours' exposure to steam or boiling water is sufficient for timbers of ordinary dimensions, and the drying afterwards goes on very rapidly, but it should be done as gradually as possible. The joiner frequently finds it necessary to steam or boil wood, to bend it into a particular curve, and also the ship-builder. It has been stated by writers on ship-building, that boiling increases the durability of timber, and in proof of this, they inform us that the planks in the bow of a ship, which are bent in this way, are never effected by the dry rot.

It may now be inquired whether, after the most perfect seasoning, timber is secured against the process of decay? To this question a negative answer must be given.—However well the timber may be seasoned it will certainly rot if placed in a damp situation, the rapidity of the decomposition depending upon the nature and state of the wood and the activity of the destroying agent. As the builder seldom attempts any other seasoning than that which depends upon drying his timbers, it is absolutely necessary that he should carefully avoid the rise of damp, and adopt every means in his power to prevent this evil. Timbers are usually placed in contact with walls, but it must not be supposed that this is sufficient to keep them from the access of damp, for they are frequently the conducting media. Brickwork very readily absorbs moisture, and also throws it upwards, so that the ends of timbers are in contact with the very source of mischief. To prevent the rise of damp upwards, it is common to use, for a few feet above the foundations, cement, a substance impervious to water, instead of mortar, or to place between the coarses zinc or slate.—But that these plans may be effective, the basement walls should be surrounded with an open area, for, if in contact with the earth on their sides, they can be of no value. To prevent dampness from entering in front, the brickwork should be covered with compo, or some substance impermeable to water.

Another thing to be considered, for the security of timbers, is to arrange, in every plan of a building, for a perfect circulation of air. Ventilation is a most important requisite in the construction of a building, although it is generally a matter of very little importance in the consideration of those who have to plan or construct buildings. The ventilation of roofs is by no means difficult, but there are often so many obstacles to the ventilation of flooring, that the designer will not give sufficient attention to his subject to

provide against them. These things, however, are not matters of speculation, to be attended to by those who have no higher employment, but are absolutely necessary for the construction of a work that is intended to survive the builder.

But we must pass from this subject to a consideration of some of those plans which have been proposed to secure well seasoned wood from the effects of dampness, and the ravages of insects, though it must be confessed that but few of them have been successful.

Attempts have been made from a very early period to prevent the destruction of wood, by impregnating it with some substance capable of restraining its ravages.—The muriate of soda, or common salt, has been thought a good preservative against decay, when the wood is thoroughly impregnated with it. The wooden posts which support the roof of a salt mine are said to be preserved by the constant infusion of salt, and that a vessel covered with fungus will have her timbers cleaned by immersion in salt-water. Whatever may be the advantages of this process, it is quite certain that it can never be extensively employed, for the salt absorbs water so readily, that the timbers would be constantly damp.

In the year 1670, a Mr. Jackson proposed to immerse timber in a composition of muriate of soda, Epsom salts, lime, potash, salt-water, and other substances; but neither he nor any body else could ever discover the value of this process. This person was permitted to prepare some timber to be used in the National yards, and it was found that vessels built with it was less durable than those in which unprepared wood was used.

Sulphate of iron, or green copperas in water has been recommended as a good mixture, in which to place wood, that is to be used for the purposes of building. It is said that timber boiled in a solution of sulphate of iron, becomes so hard when dry, that moisture cannot penetrate it. This may possibly be the case, but the change must be effected by the removal of some portion of woody fibre, and the admission of the sulphate in its place in the same manner as the wood found in the London clay has been fossilized by that substance.

Lime has been recommended as a preservative against the decay of timber. There is a difference of opinion among writers as to the value of this substance, for the particular purpose. It is well known that quick-lime with moisture rapidly destroys vegetable matter, but Mr. Tredgold says, that a large quantity of fresh quick-lime in contact with wood, absorbs the water, hardens the sap, and thus, keeping it in a perfectly dry state, renders it very durable. This gentleman quotes the opinion of Mr. Chapman, who says, that vessels employed in the Sunderland line trade have been forty years old without needing any repair, or showing the slightest evidence of decay in the timbers. A writer, who recommends the impregnation of wood with lime, says, that wood buried in the earth, and surrounded by lime, is protected from the ordinary causes of decay. But Dr. Birkbeck objects to the plan, for he says, assuming such principle to be correct, there is a great inconsistency as to the effects produced upon animal and vegetable matter, and there can be no doubt that the substance which destroys one, will destroy the other.

The attention of scientific men has been recently directed to the experiments made by Kyan, and from the very excellent exposition of his plan, by Dr. Birkbeck, we are induced to hope that it may be found highly advantageous. Having made a great number of experiments with a view to ascertain the primary cause of vegetable decomposition, he was at last convinced that albumen was that cause, and that to neutralize its effects would be to prevent decomposition. Some plan was required similar to that adopted in tanning. The gelatine in animal bodies is quite as liable to decomposition as the albumen of vegetables; but when tannin, the infusion of oak bark, is combined with it, the destructive properties are lost, and the animal matter becomes durable, and almost incapable of decay. Reasoning upon this effect, Mr. Kyan imagined that it might be possible to prevent vegetable decomposition by causing the albumen to form a combination with some other substance; and knowing the affinity of corrosive sublimate for the albumen, he entered upon a series of experiments, which led him to propose the use of that substance as a protection for timber.

A few extracts from the published lecture read by Dr. Birkbeck, before the Society of Arts, may put the subject more clearly before the reader.

"Mr. Kyan inferred that, as wood consists of various successive layers, in which the albumen, or juices containing albumen, circulated freely; it is quite certain that, as

these juices within the wood, with the watery parts, fly off by the leaves, that the albumen remains behind, and it is probable that this albumen, which from its nature is peculiarly prone to enter into new combinations, is the thing in wood which begins the tendency to decomposition, and produces ultimate decay, whether that decomposition is attended with the formation of cryptogamic substances, or whether in the less organized form, the change occurs with the simple production of what has been called the Dry Rot. He (Mr. Kyan,) conceived, therefore, if albumen made a part of wood, the latter would be protected by converting that albumen into a compound of protochloride of mercury and albumen; and he proceeded to immerse pieces of wood in this solution, and obtained the same result as that which he had ascertained with regard to the vegetable decoctions. Having done so, it became necessary to employ various modes of experiments as well as comparative experiments. Now it is not clear in what part of the wood the vegetable albumen may be found, though it exists more especially in that part of the tree which is denominated the alburnum or sap, and is found between the heart wood and the innermost layer of bark. The experience of all practical men has confirmed the opinion that this portion of wood is the first to decay.

"It is probable that, as the alburnum becomes successive layers of wood, it loses a quantity of albumen; or that, in consequence of the pressure which takes place by the addition of each successive layer, it becomes so situated, as to lose a part of its exposure to the vessels where a change may occur, and therefore becomes in some measure protected: for that which is one year alburnum or sap, may be, and indeed generally is, proper wood the next.

"The mode in which the application of the solution takes place is in tanks, which may be constructed of different dimensions, from twenty to eighty feet in length, six to ten in breadth, and three to eight in depth. The timber to be prepared is placed in the tank, and secured by a cross-beam to prevent its rising to the surface. The wood being thus secured, the solution is then admitted from the cistern above, and for a time all remains perfectly still. In the course of ten or twelve hours, the water is thrown into great agitation by the effervescence, occasioned by the expulsion of the air fixed in the wood, by the force with which the fluid is drawn in by chemical affinity, and by the escape of that portion of the chlorine, or muriatic acid gas, which is disengaged during the process. In the course of twelve hours this commotion ceases, and in the space of seven to fourteen days, varying according to the diameter of the wood, the change is complete, so that as the corrosive sublimate is not an expensive article, the albumen may be converted into an indecomposable substance at a very moderate rate, and the seasoning will take place in the course of two or three weeks."

Mr. Kyan's method of seasoning has been already tested under circumstances so severe, that they may be said to have proved its efficiency. A piece of oak was five years in the fungus pit in Woolwich yard, a place notorious for the rapid and almost instantaneous destruction of vegetable matter, and it was as sound when taken out as when put in. This was the most severe test to which the method could be subjected, and its having sustained the trial is a proof of the value of the discovery. It has, however, been objected to the process, that the impregnation of timber with corrosive sublimate must unfit it for use in ship-building; but Mr. Kyan has furnished evidence to the contrary, and in our opinion proves that salubrity is one advantage. We strongly recommend the builder to make experiments himself upon wood prepared by Mr. Kyan, by using it in places where decay is rapid.

From the Railroad Journal.

RAILROADS AND LOCOMOTIVES.

In laying the following communication before our readers, we feel compelled to reiterate the remarks made in publishing other articles on the same subject. As far as we are concerned, and as far as we understand the notions of those who have taken up the performances of Mr. Norris' and other powerful engines, as arguments against the use of stationary power and excessive excavation and embankment in ordinary cases, it is not intended to recommend the adoption of 360 nor ever of 100 feet to the mile as a suitable grade for railroads. No one can be so foolish as to propose these or any other grades as uni-

formly proper upon railroads, yet many of the remarks in the following communication as well as in others, on the same subject, are predicated upon such a supposition.

We understand these performances only as proofs of the great superiority of our American Locomotives, on any and every grade. There is no doubt but that the experiments on the Columbia Railroad give a greater adhesion than those of any former trials; but of the fact there can be no doubt. We were of a party of 53 persons, in two passenger cars, drawn with the tender up the inclined plane, rising 360 feet in a mile, at the rate mentioned in a previous No., and this without any start, the engine being stationary at the foot of the plane.

We leave the discussion of this subject, as far as the theory is concerned, to those who have time to examine into the matter.

As for Mr. Norris, he goes upon the principle that "facts are stubborn things," and we understand that in a week or two he will be able to make another and more conclusive trial of the power of his engines.

As to the remark in the communication on the blowing off of steam, we consider with the writer that this is no argument at all of sup rabundant power.

We are always obliged to our friends for communications on this subject; much discussion has already taken place in our paper, and we are convinced with a happy result.

Any remarks, facts or calculations on a theme so prolific and so intimately connected with the science of civil engineering, can never come amiss.

FREDONIA, Feb. 7th, 1837.

To D. K. MINOR, and
GEO. C. SCHAEFFER,

GENTLEMEN,—I have read in your paper of the 24th December, a Circular, by William Norris, Esq., of Philadelphia, containing an account of some very wonderful feats said to have been performed by his Locomotive Engines, on the Columbia Railroad. Some of these were published last summer, but have not as yet, I believe, been noticed by scientific men, from the fact, I suppose, that the errors in them were so enormous and so apparent, that they supposed they would be detected by all, and were not therefore worth exposing.—But the mass of those who read these accounts, now again put forth as facts, and who are interested in Railroad Improvements, are not scientific men, and it is to prevent such from daily quoting and swallowing absurdity with such grave astonishment, that I send you the following exposition. I have not the least desire to prejudice community against Mr. Norris' engines, which I have no doubt are really very superior ones, but I do not wish capitalists to mistake *steep* roads for *cheap* ones, or to suppose they are going to draw loads which are really impossible for Mr. Norris' engines or any others.

I shall confine myself to the first and last articles of this Circular, merely premising that the others are records of deeds done in equally flagrant and open violation of the laws of gravitation. In the first article in this Circular, taken from the Railroad Journal, of July 16th, 1836, it is stated that the engine "George Washington" started at the foot of a plane, having an inclination of $\frac{7}{10}$, without previously acquired velocity, and went up said plane at the rate of 15½ miles per hour, drawing a load of 19,200 pounds, with a pressure under 60 pounds per square inch in her boiler.—Now the resistance to motion which an engine must overcome when ascending an inclined plane, is composed of the following items, viz.:

1st. The friction of the load=8 pounds per ton of said load.

2nd. The gravity of the whole mass=

the whole weight multiplied by the size of the inclination.

3rd. The additional friction caused in the engine by the load it draws=1 pound per ton of said load, including gravity; and

4th. The friction of the engine without load, which varies with different engines, but is never far from 15 pounds per ton weight of the engine.

In the case before us, the friction of the load $= \frac{8 \times 19200}{2240}$ =68.56 pounds, 68.56

The gravity of the mass =34130 $\times \frac{7}{100}$ = 2389.10 pounds, g=2389.10

This being divided by 8, gives 298.63, to which adding 8.57 (the weight of the engine in tons), gives a total load=307.20 tons on a level, 307.20

which causes therefore an additional friction of 307.20 pounds, 100.00

R=2864.86

The friction of the engine without load $= \frac{15 \times 14930}{2240}$ = 100.00 pounds, making in all, a resistance R=2864.86, to which the power applied to the engine must at least be equal, in order that it should advance.

The dimensions of the "Goorge Washington" are thus given:

D=diameter of driving wheels =48 inches, D=48

d=diameter of cylinders =10.25 inches, d=10.25

l=twice the length of the stroke=35.25 inches, l=35.25

W=weight of engine=14.930 pounds, W=14.930

w=adhering weight=8700 w=8700

π=3.1416

The area of both pistons will be $\frac{1}{2}\pi d$= 165 sq. in., which being multiplied by 60, the pressure per square inch, *below* which it is stated the engine worked, and we have 9900 pounds power applied to the pistons; but as the power applied to two different points in the same machine is in the inverse ratio of the velocity of those points, and as the velocity of the piston is to that of the engine, as twice the length of the stroke to the circumference of the driving wheels, the 9900 pounds power applied to the piston, must be multiplied by the ratio $\frac{l}{\pi D} = \frac{1}{4.278}$ to transfer it to the engine. This gives the power of the engine ρ=2314.16 pounds, which it will be seen by refering to the table of resistances above, *was insufficient to overcome the force of gravity*. Therefore supposing the "George Washington" to be one of those Utopian Motors, which move themselves and thei loads without a pound of friction, yet the feat is impossible, without we can also "suspend the rule," with reference to the immutable law of gravitation. In the case of no friction, the engine placed upon the plane, with the forces applied exactly as stated to have been, instead of going *up* the grade, would go *down*, impelled by a constantly accelerating force, equal to $(g - \rho)$=75 pounds. *Actually*, the engine would have remained in equilibrium on the plane, the surplus of gravity over the power of the engine being insufficient to overcome the friction which retards the *downward*, as well as the upward motion.

The statement thus demonstrated so vitally wrong, ones confidence in the whole experiment is greatly impaired. For instance, I am inclined to believe, that the load actually drawn up the plane, was not so great as stated, since this gives for the adhesion a value of about $\frac{1}{3}$ the adhering weight, which is more than twice as great as any yet observed elsewhere. But supposing the load to have been exactly as stated, then the pressure in the boiler and

cylinders must have been enormously greater. It is easy to calculate *how much* greater it must *necessarily* have been.—The analytical expression for the effective pressure in the boiler of an engine, in order that it may draw a given maximum load, is thus given by Pambour, $\rho - \delta = \frac{D\,(9\,M + F)}{\frac{1}{2}\,l\,d^2}$ in which ρ represents the elastic force of the steam, δ = the atmospheric pressure per same square unit, and F, the friction of the engine without load. In this formula, putting for the Algebraic quantities their values, we have the effective pressure $\rho - \delta = \frac{48 \times (2763 + 100)}{(\frac{4}{4})^2 \times (\frac{14}{8})} = 74.2$, so that the engine must have worked at the pressure of 74.2 pounds per square inch.

The Editor of the "National Gazette" concludes his comments on this performance with the following: "It is remarkable that the engine was blowing off, on her arrival at the top, having acquired *speed!* and power during the ascent." It is indeed "remarkable" that this sapient editor did not know, that the blowing, instead of indicating a gain of speed, was occasioned by the loss of it. If an engine goes a certain speed, and if by some obstacle her speed is reduced to one half, the fire being animated the same as before, about the same amount of steam is generated in the boiler in the same time, while only half the number of cylinders of steam is used—the consequence is, that the pressure rises in the boiler which lifts the valve, and causes the blowing which was so edifying to the Editor of the Gazette.

I now come to the last article in the Circular, wherein Mr. Norris states that the engine, "Washington County Farmer," drew 141¾ tons, over a rise of 47 feet per mile, at the velocity of 22 miles per hour. In this case, the whole resistance R = 4759 pounds. The dimensions of this engine are not given, but supposing the ratio $\frac{l}{\pi D}$ the same as in the "George Washington," and the diameter of the pistons = 11 inches, such an enormous pressure is required as to throw an air of incredulity over the performance. Please give if you can, the dimensions of this engine, and the pressure employed on this occasion.

Your obedient servant,

A. G. Steere,

New-York and Erie Railroad.

Items.

From the 1st of May to the 31st of December, 1836, 730,000 passengers were conveyed on the railroad from Antwerp to Brussels; the receipts amounted to 734,-236f.

Pig iron has been reduced by the iron works in the neighborhood of Bradford, £1 a ton. A similar reduction has taken place in Wales.—[Times.]

The *German Courrier* gives the following of the 12th inst., from Vienna:—"Some new iron mines of considerable extent have been discovered at Eisenertz, in Styria, which place has long been celebrated for its rich mines of that metal; upwards of three hundred thousand quintals are annually drawn from the mines of Erzberg, and it is thought that those just discovered will be equally productive. It has been declared by persons acquainted with the article that the Styrian steel is harder and more flexible than that of England, with which it can also compete in cheapness of manufacture.—English steel costs here from 120 to 160 florins the quintal; whereas the price of the quintal of Styrian steel will not exceed 60 florins. Austria may therefore dispense with English steel, while that of Styria will become an important branch of commerce, not only in Europe, but in other parts of the world. The Prince Lobkowitz encourages with all his efforts this new undertaking, which yields abundant profit."

The River Thames.—The removal of the old London Bridge has caused a considerable change in the river above, and also, though in a less degree, below the

bridge. Owing to the contracted arches through which the water had to make its way at the old bridge, there was a fall of from 4 feet 9 inches to 5 feet at low water; this fall is now reduced to about 2 inches; so that the low water line above the bridge is nearly 5 feet lower at spring tides than formerly. In consequence, a greater increased body of tidal water now flows up and down the river. The effect of this is to scour and deepen the channel of the river; its influence in this respect being sensibly felt as far up as Putnam Bridge, 7½ miles above London Bridge. The shores above the latter, that were formerly foul and muddy, are now becoming clean shingle and gravel, and near low water the beach is quite hard and firm. The shoals are also decreasing below the bridge; and there can be little doubt that the change will, at no distant period, be felt from the Nore up to Teddington. The descent down the river has been equally facilitated; the mean velocities of the flood and ebb between London and Westwinster-bridge are, flood three miles an hour, extreme three-and-a-half; ebb three ⅙; extreme three ½.—[Herald.]

A mechanician of Cherbourg has just invented a press for the extraction of oil, which possesses very decided advantages over every other press hitherto in use, as a greater power can be given to it, and it will extract twice the quantity of oil in the same time as the other presses hitherto in use.—The force of a single man applied to this machine will produce a pressure equal to 400,000 pounds weight. The new press also occupies but little room, as it will stand in the space of four square feet.

The National Intelligencer gives the following biographical sketch of the late John Loudon McAdam:

Mr. McAdam was of the proscribed clan of the McGregors, being, in his own person, the head of one of the branches of that family, of which the territorial appellation was Waterhead. His father took the name of McAdam, when that of McGregor was forbidden. In early youth, Mr. McAdam came to this country, as the adopted son and heir of an uncle of the same name, whose widow died within the last ten years in New-York. After residing here seventeen years, during which period he married, Mr. McAdam returned to England and established himself near Bristol. At this place he commenced, about the year 1810, those experiments which have since converted the roads of England into the best in the world. By this improvement he has made himself one of the great benefactors of that nation, and indeed, of our own, though his system has been but lamely imitated here. He was conscious of the extent of his services, which have never received the reward they deserved. He was twice offered knighthood, and once a baronetcy by the British government, both of which titles he declined, preferring his confiscated but hereditary claims to "Waterhead," with true Scottish fidelity, to the possession of those more common distinctions. His second son has, however, recently accepted the former rank, and is the present Sir James McAdam. As this gentleman occupies the situation of superintendent of the metropolitan roads, he is commonly mistaken for his father.

Mr. McAdam was twice married, and both times to ladies of well known New-York families. His first wife was Gloriana, the daughter of William Nicoll, Esq., of Islip, the collateral descendant and heir of Col. Nicoll, the first English governor of the colony, and the proprietor of one of its largest manors; and his second wife was Anne Charlotte De Lancey, the eldest daughter of John Peter De Lancey, Esq., of Mamaroneck, Westchester, whose father died at the head of the government of the same colony in 1769. By his first wife, he left several children.

At Saint Denis de Thibeult, near Rouen, a discovery has lately been made of a large spherical Roman vase, of Terra Cotta, 5½ feet in circumference, inclosing a square vitrified vase, about a foot high, filled with burnt bones and ashes. These relicts are in perfect preservation, and M. Quesnel, on whose estate they were found, about four feet below the surface, has deposited them in the museum of antiquities at Rouen.

We have it from undoubted authority that a propelling power has been discovered for vehicles on common roads, which can be applied to mail coaches, etc., at the cost of 6d. per mile for a four horse power.—The invertor has obtained a patent in England, and is obtaining a similar instrument in the principal countries of Europe, and in the United States.—[Cumberland Packet.]

TRANSACTIONS

OF

THE INSTITUTION

OF

CIVIL ENGINEERS.

VOLUME I.

LONDON:

1836.

RE-PRINTED, IN NUMBERS, AT THE OFFICE OF THE RAILROAD JOURNAL, 30 WALL-STREET, NEW-YORK, BY

D. K. MINOR, AND GEORGE C. SHAEFFER.

1837.

I. ON THE CHANGES OF TEMPERATURE CONSEQUENT ON ANY CHANGE IN THE DENSITY OF ELASTIC FLUIDS, CONSIDERED ESPECIALLY WITH REFERENCE TO STEAM.

By MR. THOMAS WEBSTER, M. A. OF TRINITY COLLEGE, CAMBRIDGE. Communicated by MR. JAMES SIMPSON, M. INST. C. E.

My attention having been for some time directed to the theory and constitution of fluids, it has appeared to me that there are some properties of which little notice has been taken, but which, being of considerable practical importance, ought to receive the attentive consideration of scientific men, and especially of those who possess the opportunities of deciding on their value. On the present occasion I beg to offer a few observations respecting these properties. I wish, then, to call attention to the *change of temperature* which always accompanies a *change in the density* of an elastic fluid, and to the consequent change in the elastic force due simply to that change in temperature, as distinguished from the change which is due to the change of density according to the law of Boyle. It has long been observed, that the sudden compression of any quantity of air is attended with a great degree of heat, and its sudden expansion with a great degree of cold. Thus, if a piston, having a small piece of tinder attached to it, be pressed suddenly down in a cylinder of air or gas, the heat evolved, or squeezed out, by the compression will ignite the tinder; and again, if a delicate thermometer be placed under the receiver of an air-pump, it will indicate cold produced on every stroke of the pump. These effects will not continue long, since there will be an immediate transfer of heat, according to the well known laws of the radiation of heat; thus the heat evolved by the condensation will be rapidly lost among, and that absorbed by the expansion will be supplied from, the surrounding bodies, the general fact being, that the temperature always tends rapidly to equilibrium. The beautiful and simple apparatus of Gay-Lussac may be mentioned, since it exhibits at once both the phenomena in question. Let two spherical glass vessels communicate with each other by a stop-cock, and have a delicate thermometer suspended at their centres; then if one have the air exhausted, and the other be filled by a condenser, either with common air or with a gas, and the stop-cock be opened so that the condensed air rushes into the empty vessel, the thermometer in one vessel will sink and in the other will rise; namely, it will sink in that which is being emptied, or in which the air is expanding, and it will rise in that which is filling, or in which the air is being condensed; and when the experiment is made with great care, it will be seen that the cold indicated by one corresponds exactly to the heat indicated by the other. If another thermometer be suspended in the empty vessel close by the orifice, that is, just where the air is in the act of expanding, a very great degree of cold will be indicated; and this will diminish rapidly as it is placed further from the orifice. These indications of heat and cold continue but for a very short period, since the equilibrium of temperature is almost instantaneously restored. No accurate measure of the heat absorbed and developed can be procured by direct observations on the thermometer; it may, however, be calculated from the change in the elastic force, as we shall see presently. This experiment of Gay-Lussac does not appear to have been repeated on a large scale; but I conceive that if a large cylinder of thin metal were placed in communication with a vessel of condensed air at a great pressure, the cold produced at the one end, where the expansion was proceeding, and the heat produced at the other, where the condensation was taking place, would be quite sensible to the hand, and a series of air-thermometers would indicate very different states of temperature at the same distances from each end. But the important practical inquiry is the change which this developement and absorption of heat produces on the elastic force of the fluid; there must be increase of elastic force due to this increase of temperature, and a diminution of elastic force due to the diminution

of temperature, besides the increase and diminution which is due to the change of density according to Boyle's law. In fact, we know that Boyle's law is not true, unless the compressed air is allowed time to cool, as was distinctly ascertained in the series of experiments made by order of the Academy of Paris on this subject. In the complete investigation of it by Desormes and Clements, which I have detailed at full length in my Theory of Fluids, Article 98, the increment of temperature is calculated by a series of mathematical reasoning, from this very change in the elastic force for which I contend. The problem proposed was "to determine the increment of temperature for a given small condensation." They observed the successive changes which the mercurial column underwent when air was first let into an exhausted receiver, and after it had lost the small increase of temperature due to the small condensation. The column always sunk by a small quantity, and the amount of this change enabled them to determine the amount of heat developed for a given condensation. Of the accuracy of their results there cannot be the least doubt, for two other and quite independent phenomena, in which the same causes are called into operation, namely, the production of sound and the vibration of a cylindrical column of air, give results according with very great accuracy. The preceding facts are mentioned, to give confidence in the principle for which I contend, that whenever there is a change in elastic force according to the law of Boyle due to the density, there is also an additional change in the elastic force due to the change of temperature, which is the necessary consequence of this change in the density: for it must be remembered, that in all the experiments, the elastic force agrees with the law of Boyle so soon as the equilibrium of temperature is restored.

On this part of the subject it is unnecessary to insist, since the facts are well established for most of the elastic fluids, but the experiments, so far as I have become acquainted with them, do not extend to steam, and unless there be some reason for excluding steam from the general properties of all other elastic fluids, we must admit the preceding conclusions with respect to it also. Now so far from having any reason to except steam from these laws, we have every reason for believing that steam separated from its water, and maintained at a higher temperature than 212°, differs in no respect from the permanent gases. It can be readily liquified, but doubtlessly all the gases can be reduced to the same form by a proper increase of pressure and diminution of temperature.

For if we consider steam as an elastic fluid owing its elastic qualities solely to the repulsive power of heat, there can be no reason *a priori* for excepting it from the laws of other elastic fluids, which appear to owe their energy and existence to the same cause. Now so far as experiments have been made, it appears that steam expands equally for all equal increments of temperature; thus following the law of other elastic fluids. There is a passage in Professor Robinson's Treatise on Steam which involves the principle in question, but which appears not to have been followed out. He says, "it is well "known that when air is suddenly expanded, "cold is produced, and heat when it is sud- "denly compressed. When making expe- "riments with the hopes of discovering the "connexion between the elasticity and den "sity of the vapors of boiling water and "also of boiling spirits of turpentine, we "found the change of density accompanied "by a change of temperature vastly greater "than in the case of incoercible gases. "When the vapor of boiling water was "suddenly allowed to expand into five times "its bulk, we observed the depression of a "large and sensible thermometer to be at "least four or five times greater than in a "similar expansion of common air at the "same temperature."

The fact of the depression being greater in the expansion of steam than of air at the same temperature, is explicable at once from the different constitutions of the two fluids with respect to the properties of heat; but on this I cannot at present enter. The fact is invaluable as coming from such a man, and, when viewed in connexion with the general theory of elastic fluids, and the abovementioned law of Gay-Lussac respecting the expansion of steam for increments of temperature, entitles us to assume that, so long as steam retains its gaseous character, it is subject to the laws of gases. These conclusions might be sustained by many well known phenomena respecting vapors and evaporation generally, but enough has been said to warrant our including steam in the general law of the French philosophers respecting elastic fluids: "That equal volumes of

"all elastic fluids, taken at the same tempe-
"rature and the same pressure, being sud-
"denly compressed or expanded by the
"same fraction of their volume, disengage
"or absorb the same absolute quantity of
"heat."

Now the degree of heat or cold produced depends on the rate at which the change takes place; and this consideration will lead to some important conclusions with respect to the expansion of high-pressure steam. The rate of expansion will obviously depend on the elastic force of the steam; the higher pressure therefore which we use the greater will be the cold and the greater the diminution of the elastic force beyond that which the law of Boyle would give. Suppose steam of ten atmospheres suddenly to expand to four times its bulk, then the elastic force of the expanded steam ought, on these principles, to be much less than the elastic force of steam of five atmospheres suddenly expanded to twice its bulk; and the greater the elastic force of the steam, the greater will be the deviation from the law of Boyle. So that, while Boyle's law will be nearly true for steam of one or two atmospheres, it will be most untrue for steam of five or ten atmospheres. These, I conceive, are results which may be readily tested by careful experiments. I know of none in which they have been fairly examined, for I am not willing to admit the conclusions which may be drawn from some accounts of steam worked expansively, and which would appear to militate against these principles; but on this I shall say more immediately.

It would appear then, that the mere rate of expansion may be such, that the diminution of elastic force, consequent on the diminution of temperature, may leave scarcely any elastic force in the expanded steam; so that there may be extreme cases in which the law of Boyle will appear absolutely false. These conclusions appear to me supported and illustrated by the facts, that high pressure steam does not scald, and that elastic steam is not so efficacious as gunpowder for throwing bullets or other masses.

When low pressure steam expands into the air, it preserves very nearly both its density and its temperature, but when steam of a high pressure expands, the instantaneous augmentation of volume demands that a large portion of heat should become latent, or it cannot exist at all as steam. If the expansion were to stop the instant at which the elastic force of the steam becomes equal to that of the atmosphere, its temperature would (since the sum of the sensible and latent heat is invariable) descend only to 212°; but in consequence of the momentum which the particles have acquired from the rapidity of the expansion, it expands far beyond this limit, so that the diminution of temperature becomes greater, in proportion as its original elastic force was greater than the elastic force of the atmosphere. If this expansion takes place in a vacuum, the reduction of temperature will be greater still, since the particles of air present mechanical obstacles to the expansion. So that in some cases the elastic force may be lost almost entirely. We know, thanks to the ingenuity of Mr. Perkins, that highly elastic steam will impel bullets with considerable velocity; this velocity does not, however, appear to be equal to that which can be generated by gunpowder. Now in order to increase the velocity, we must increase the elastic force of the steam, the consequence of which being an increased rapidity of expansion, the additional reduction of temperature may more than nullify the original increase of elastic force, so that steam at a higher pressure will be less efficacious than steam of a less pressure. If this be the case, there is some temperature at which for a given ball the effect is a maximum, that is, greater than either at a higher or a lower temperature. But in the case of gunpowder the temperature of the elastic fluid is kept up by the continued consumption of fresh materials; the heat evolved during the combustion of these ingredients is quite prodigious, so that we have, in fact, the repulsive power of heat itself in full agency. I have said nothing respecting the density of the steam at different temperatures, my object not being to discuss this question fully, but merely to illustrate what must, I conceive, be the necessary consequence of increasing the temperature and elasticity of the steam beyond certain limits.

The application of these principles to the working of *steam expansively* is at once apparent; there will in every case be a diminution in the pressure exerted beyond what will be given by Boyle's law, and this will be greater the more rapidly the engine is worked. But on this subject I hardly dare venture any remarks; practical considerations are of much greater value than any which I can offer, especially as in one large class of engines, namely, in condensing engines,

where the steam is worked at a low pressure, the deviations from the Boylean law, due to the cause which I have mentioned, cannot be considerable; still, however, these deviations must, I conceive, be appreciable whenever the steam is generated at a higher temperature than 212°. But in high pressure engines the deviations due to this cause must be considerable, and I would venture to suggest that if higher pressure steam be used than is from the circumstances of the case practically necessary, the steam generated is not applied in the most economical manner, so far as concerns the ratio of the work done to the fuel consumed. The preceding remarks have referred exclusively to steam separated from its water and maintained at such a temperature that it may be considered as a permanent gas. If the steam be not separated from its water, the case is so entirely different, that the preceding remarks do not at all apply.

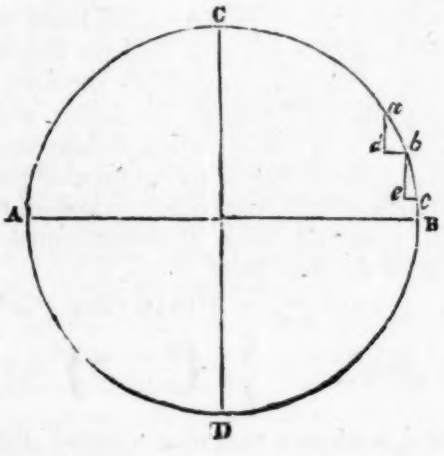
If the space above the water be not saturated with vapor, that is, if the vapor which it contains have not the maximum density due to the temperature of the water, it is owing to the mechanical obstruction of the particles of air; but since we suppose the air removed, or the space full of steam, we have to consider the nature of the changes which take place when this given space is increased or diminished, that is, when the pressure on the surface of the water is diminished or increased. In this case the law of Boyle has no existence, for it applies only to a permanent gas, that is, it is only a steam law, when the vapor is detached from its liquid and contained in a space of such a temperature that it may be considered as a permanent gas. The pressure of the existing vapour on the surface of the water being the only limit to the formation of fresh vapor, whenever the pressure on this surface is diminished in the boiler by the withdrawal of a portion of the steam, fresh steam will instantly be formed, so that if, where steam is worked expansively, there be any water at the bottom of the cylinder, or any communication whatever with any water, the effect will be precisely the same as if the communication with the boiler were not entirely cut off; there will be a constant accession of steam, or fresh steam will be formed as fast as the piston rises. It has sometimes been stated that where steam is worked expansively, the effect is greater than the Boylean law would lead us to suppose; if such appear to be the case, it must be from some such cause as the above mentioned; either the steam is not entirely cut off, or there is some communication with water: the smallest quantity of water will be sufficient to increase very considerably the apparent effect, and cause a great deviation from the calculated elastic force. The whole theory of this subject is so intimately connected with the theory of heat, that the consequence of its known laws may be immediately traced in every application of steam; hence we may be convinced that there is a loss of elastic force, besides that which is due to the change in density, whenever steam is worked expansively, however much it may be practically overruled and modified. As a means of detecting this I would mention, that it ought to be shown by the greater supply of heat which a cylinder requires when the steam is worked more expansively, than where the same steam is worked less expansively. From these considerations we may see that there is a maximum in the useful effect of expansion working; but the complete determination of it is a purely practical question, and since it will depend on the conducting power of the metal, it must be somewhat different for every different engine.

II. ON THE FORCE EXCITED BY HYDRAULIC PRESSURE IN ABRAMAH PRESS; THE RESISTING POWER OF THE CYLINDER, AND RULES FOR COMPUTING THE THICKNESS OF METAL FOR PRESSES OF VARIOUS POWERS AND DIMENSIONS. BY PETER BARLOW, F. R. S. ETC., OF THE ROYAL MILITARY ACADEMY.

I am not aware that any of our writers on mechanics have investigated the nature and amount of the circumferential strain which is excited in an hydraulic cylinder by a given pressure on the fluid within; it will be proper, therefore, first to examine this question: viz., to find the circumferential strain on a ring of any material, arising from an internal pressure.

Let *ab*, *bc*, be any small elementary part of the circumference, which may be taken as right lines, and let the pressure on each of them be called *p*, which, being proportional to them, may be represented by the elements themselves, *ab*, *bc*, these being perpendicular to the direction in which the pressure acts. Resolve these pressures or forces into two rectangular forces, *ad*, *db*, *be*, *ec*, of which,

ab, and *be*, will represent forces acting perpendicular to their direction or parallel to



A B, and *db* and *ec* forces parallel to D C. Confining ourselves at present to the former, if we conceive the semi-circumference D B C to be divided into its component elements, it is obvious that the sum of the forces acting parallel to A B, will be equal to the sum of all the perpendiculars, *ad*, *be*, or to the whole diameter D C. That is, the sum of all the forces acting parallel to A B, will be to the sum of all the forces or pressure on the semi-circumference D B C, as the diameter to the semi-circumference. But the pressure on the semi-circumference is equal to the number of inches in the same, multiplied by the pressure per square inch, consequently the force or pressure exerted parallel to A, B, will be equal to the inches in the diameter, multiplied by the pressure per square inch, the ring being here supposed, for the purpose of simplification, only an inch deep. But to resist this pressure, we have the two thicknesses of the ring at D and C; therefore the direct strains on the circumference at any one point, as D, will be equal to the pressure of the fluid per square inch, multiplied by the number of inches in the radius.

We should come to the same result more simply, but perhaps not so satisfactorily, by conceiving a section passing through the diameter D C; then it follows that the pressure on this section, which is directly resisted at D and C, is equal to the number of square inches in the section, multiplied by the pressure per square inch. Therefore the strain on D or C singly, is equal to the pressure per square inch multiplied by the inches in the radius; the same as above.

TO INVESTIGATE THE NATURE OF THE RESISTANCE OPPOSED BY ANY GIVEN THICKNESS OF METAL IN THE CYLINDER OR RING.

It would appear at first sight, that having found the strain at D and C, it would only be necessary to ascertain the thickness of metal necessary to resist this strain when applied directly to its length; this, however is by no means the case, for if we imagine, as we must do, that the iron, in consequence of the internal pressure, suffers a certain degree of extension, we shall find that the external circumference participates much less in this extension than the interior, and as the resistance is proportional to the extension divided by the length, according to the law *ut tensio sic vis*, it follows, that the external circumference, and every successive circular lamina, from the interior to the exterior surface, offers a less and less resistance to the interior strain: the law of which decrease of resistance it is our present object to investigate.

In the first place, it is obvious that whatever extension the cylinder or ring may undergo, there will be still in it the same quantity of metal, or which is the same, the area of the circular ring, formed by a section through it, will remain the same, which area is proportional to the difference of the squares of the two diameters.

Let D be the interior diameter before the pressure is exerted, and $D+d$ its diameter when extended by the pressure. Let also D' be the external diameter before, and $D'+d'$ the diameter after the pressure is exerted; then from what is stated above it follows, that we shall have

$$D'^2 - D^2 = (D'+d')^2 - (D+d)^2$$

or, $2D'd' + d'^2 = 2Dd + d^2$

or, $2D' + d' : 2D + d :: d : d'$

or since d' and d are very small in comparison with D' and D, this analogy becomes $D' : D :: d : d'$. That is, the extension of the exterior surface is to that of the interior as the interior diameter to the exterior.

But the resistance is as the extension divided by the length, therefore the resistance of the exterior surface is to that of the interior as $\frac{D}{D'} : \frac{D'}{D}$ or as $D^2 : D'^2$. That is the resistance offered by each successive lamina, is inversely as the square of the diameter, or inversely as the square of its distance from the centre; by means of which law

the actual resistance due to any thickness is readily ascertained.

Let r be the interior radius of any cylinder, p the pressure per square inch on the fluid, t the whole thickness of the metal, and x any variable distance from the interior surface. Let also $rp=s$ represent the strain exerted at the interior surface, according to the principles explained in the preceding part of this paper. Then by the law last illustrated we shall have

$(r+x)^2 : r^2 :: s : \frac{r^2 s}{(r+x)^2}$ for the strain at the distance x from the interior surface: and consequently $\int \frac{r^2 s dx}{(r+x)^2} + \text{Cor.} =$ the sum of all the strains, or the sum of all the resistance. This becomes, when $x=t$, $R=r^2 s \left(\frac{1}{r} - \frac{1}{r+t}\right) = s \frac{rt}{r+t}$. That is, the sum of all the variable resistances due to the whole thickness t, is equal to the resistance that would be due to the thickness $\frac{rt}{r+t}$ acting uniformly with a resistance s, or rp.

APPLICATION OF THIS RULE FOR COMPUTING THE PROPER THICKNESS OF METAL IN A CYLINDRIC HYDRAULIC PRESS OF GIVEN POWER AND DIMENSIONS.

Let r be the radius of the proposed cylinder, p the pressure per square inch on the fluid, and x the required thickness: let also c represent the cohesive strength of a square inch rod of the metal.

Then from what has preceded it appears, that the whole strain due to the interior pressure will be expressed by px, and that the greatest resistance to which the cylinder can be safely opposed is $c \times \frac{rx}{r+x}$: hence when the strain and resistance are in equilibrio, we shall have

$$(1) \quad rp = \frac{rx}{r+x} \times c$$

$$\text{or } pr + px = cx$$

whence $x = \frac{pr}{c-p}$ (the thickness) sought.

Hence the following rule in words for computing the thickness of metal in all cases; viz, multiply the pressure per square inch by the radius of the cylinder, and divide the product by the difference between the cohesive strength of a square inch rod of the metal and the pressure per square inch, and the quotient will be the thickness required.

At present we have only considered the circumferential strain: to find the longitudinal strain, we have to multiply the area of the piston by the pressure per inch; while the resistance in this direction will be equal to the cohesive power of the metal multiplied by the area of the transverse section of the cylinder; so that when these are equal to each other we shall have

$$(2) \quad 3{\cdot}1416\, r^2 p = 3{\cdot}1416\, (2rx + x^2)c$$

which gives $x = r \left\{ \sqrt{\left(\frac{p}{c} + 1\right)} - 1 \right\}$

And it is obvious that whichever of these two values of x, viz., (1) or (2,) is the greatest, is the one which must be adopted. It will appear, however, that in all practical cases the former is the greater; for it is only when p exceeds c that the latter value of x can be ever equal to the former. Let us, for example, find the relative values of p and c, when these values of x are equal to each other, by making

$$\frac{rp}{c-p} = r \left\{ \sqrt{\left(\frac{p}{c} + 1\right)} - 1 \right\}$$

this gives

$$\frac{p^2}{(c-p)^2} + \frac{2p}{c-p} = \frac{p}{c}$$

$$\text{or} \quad p^2 c + 2pc\,(c-p) = p\,(c-p)^2$$

$$\text{or} \quad p^2 - pc = c^2$$

$$\text{whence} \quad p = c\,(\tfrac{1}{2} \pm \tfrac{1}{2}\sqrt{5})$$

That is, these two values of x can only be equal to each other when p exceeds c in the ratio of $(\frac{1}{2} \pm \frac{1}{2}\sqrt{5}) : 1$; which is an impracticable pressure; for it is obvious from the first value of x, that no thickness will be sufficient to resist an internal pressure which exceeds (per square inch) the cohesive power of a square inch rod of the metal; a result which at first sight appears to be paradoxical; but it will be observed that, with such a pressure, the interior surface will be fractured before the other parts of the metal are brought into action.

It will therefore be sufficient to attend wholly to the first expression; and here it may be observed that x and r, with the same pressure and cohesive power, being always in the same ratio, we may reduce the rule for finding the thickness of metal to the following tabulated form, in which it will only

be necessary to mutiply the number standing against any pressure by the internal diameter of the cylinder or piston for the thickness required.

The cohesive strength of cast iron, according to experiments made at Capt. Brown's manufactory, is 7·26 tons per square inch; but his machine underrates its power 8 per cent.; (see my Essay on the Strength of Wood and Iron, page 258, 2d edition;) this added, gives us 7·86 tons, or 17,612 lbs., per square inch.

Mr. Rennie gives two results for the cohesive power of cast iron, viz.,

1st . .	= 18,656
2d . .	= 19,072
My experiment	= 17,612
Mean . .	= 18,685

We may, therefore, without sensible error, call the cohesive power 18,000 lbs. per square inch.

The cohesive power of the best gun-metal is given by Mr. Tredgold, in his edition of Buchanan's Treatise on Mill Work, 36,000 lbs. per square inch, and that of lead, 3328 lbs. per sq. inch; and with these numbers I have computed the following thickness for pipes of an inch diameter, for the various pressures given in the Tables, and which will apply to any other case by multiplying the tabular numbers by any given diameter.

TABLE FOR COMPUTING THE THICKNESS OF CAST IRON PIPES AND CYLINDERS.

COHESIVE STRENGTH OF CAST IRON, 18,000 lbs.							
PRESSURE.	THICKNESS.	PRESSURE.	THICKNESS.	PRESSURE.	THICKNESS.	PRESSURE.	THICKNESS.
1000	·0294	2000	·0625	3000	·1000	4000	·1438
1100	·0325	2100	·0660	3100	·1040	4500	·1666
1200	·0357	2200	·0696	3200	·1080	5000	·1922
1300	·0388	2300	·0732	3300	·1122	5500	·2200
1400	·0421	2400	·0769	3400	·1164	6000	·2499
1500	·0454	2500	·0806	3500	·1207	6500	·2827
1600	·0487	2600	·0844	3600	·1250	7000	·3181
1700	·0521	2700	·0883	3700	·1293	7500	·3570
1800	·0555	2800	·0921	3800	·1337	8000	·4000
1900	·0590	2900	·0959	3900	·1382	8500	·4462

TABLE FOR COMPUTING THE THICKNESS OF GUN-METAL CYLINDERS; APPLICABLE ALSO TO GUNS AND MORTARS.

COHESIVE STRERGTH OF GUN-METAL, 36,000 lbs.							
PRESSURE.	THICKNESS.	PRESSURE.	THICKNESS.	PRESSURE.	THICKNESS.	PRESSURE.	THICKNESS.
1000	·0143	2000	·0294	3000	·0454	4000	·0625
1100	·0157	2100	·0309	3100	·0471	4500	·0714
1200	·0172	2200	·0325	3200	·0487	5000	·0806
1300	·0187	2300	·0341	3300	·0504	5500	·0901
1400	·0202	2400	·0357	3400	·0521	6000	·1000
1500	·0217	2500	·0372	3500	·0538	6500	·1102
1600	.0232	2600	·0388	3600	·0555	7000	·1207
1700	·0247	2700	·0405	3700	·0572	7500	·1315
1800	·0263	2800	·0421	3800	·0590	8000	·1428
1900	·0278	2900	·0438	3900	·0607	8500	·1543

TABLE FOR COMPUTING THE THICKNESS OF LEAD CYLINDERS, WATER PIPES, ETC.

COHESIVE STRENGTH OF SHEET LEAD, 3320 lbs.					
PRESSURE.	THICKNESS.	PRESSURE.	THICKNESS.	PRESSURE.	THICKNESS.
5	·00075	100	·0155	1100	·2477
10	·001510	200	·0320	1200	·2830
20	·003030	300	·0496	1300	·3217
30	·004559	400	·0684	1400	·3645
40	·006097	500	·0886	1500	·4120
50	·007645	600	·1102	1600	·4651
60	·009202	700	·1335	1700	·5246
70	·010769	800	·1587	1800	·5921
80	·012345	900	·1859	1900	·6690
90	·013931	1000	·2155	2000	·7575

For a pressure not found in any of the above Tables, it will be sufficiently correct to use the following proportion, viz:

As the difference of the two tabular pressures, between which the given pressure falls; is to the difference between the corresponding tabular thickness, so is the difference between the lesser tabular pressure and the given pressure, to the difference between the lesser tabular thickness and that required. Suppose, for example, the thickness for a cast iron cylinder were required for a pressure of 3650 lbs.

Pressure	3700	Thickness	·1293
Do.	3600	Do.	·1250
Difference	100	Difference	·0043

100 : ·0043 :: 50 : ·0021

Therefore ·1250
·0021

1271 the thickness sought.

As another example of the use of the Table, let the thickness of a cast iron cylinder be required, that will bear a proof pressure of 3 tons per circular inch, the interior diameter being 12 inches.

$$\text{Here } \frac{3 \text{ tons}}{\cdot 7854} = 3\cdot 819 \text{ tons or } 8554 \text{ lbs.}$$

per square inch. Call this 8500 lbs.; then, by Table I., the thickness for an inch cylinder is ·4462, consequently $4462 \times 12 = 5\cdot 3544$ inches, the thickness required.

It will of course be understood that the thicknesses given in the Table are the least that will bear the required pressure, and that, in common practice, presses ought not to be warranted to bear above one third the pressure given in the Table, unless it should appear that the estimated cohesive power of cast iron is too little; if this actually exceed 18,000 lbs., a corresponding reduction may be made in the computed thicknesses.

III. AN ACCOUNT OF SOME EXPERIMENTS ON THE EXPANSION OF WATER BY HEAT. BY THE LATE T. TREDGOLD, M. INST. C. E.

The expansion of water, by increase of temperature, is one of those experimental subjects that has not received the degree of attention its importance would lead us to expect; but, as even the smallest addition to any part of knowledge contributes towards its increase, I have ventured to send this mite for the consideration of the members of the Institution.

I began by a series of trials with a thermometer, containing water instead of mercury, to find the point at which the volume of water is a minimum, by cooling successively down to 32° with snow and water, and observing the decrease of bulk, which continued till the temperature was 40°; the rise again was then sensible. In like manner by cooling, the decrease continued till the temperature was about 39°, when the rise became sensible. So small and uncertain, however, was the rate of increase or decrease, that we may practically estimate 40° as the temperature corresponding to the maximum density of water.

Having marked the tube at the point when the temperature was 40°, and also another point within the range of the tube, I divided the distance between these, into four equal

parts. With this precaution I immersed the water themometer, and a mercurial one, in a vessel of hot water, and as it cooled compared the temperatures as the water contracted to each division on the tube. The mean of several trials was as follows:

Temp.	112°	4th or upper division.
—	104°	3d.
—	90°	2d.
—	74°	1st division.
—	40°	maximum density.

I intended to repeat the trials and to correct these numbers; but the cold weather commenced, and instead of attending to the higher degrees of heat, my attention was directed to the lower ones. The bulb of the thermometer was immersed in a mixture of snow and salt, and a mercurial one placed beside it, but I found the two were not alike affected by the mixture; the water thermometer rose rapidly till it arrived at, or very near to the third division on the tube, when it exploded. At the moment of explosion, the central part of the mass of water, and that in the tube were both perfectly fluid, and the fragments of the bulb were lined with a thin coat of ice, beautifully crystallized. The fractured bulb presented a singular appearance, the whole being cracked into very fine gores, somewhat less than one-twentieth of an inch in breadth at the middle, and exceedingly regular.

The temperature of a mixture of snow and salt is —5°, or 5 degrees below zero; hence, if the expansion below 40° had been the same as far above 40° the thermometer ought not to have risen quite to the second division; but, as it rose very nearly to the third division, it seems that the expansion below 40° is much greater than at a corresponding number of degrees above 40°; and that the common opinion is not quite correct in this respect.

I have not had leisure to follow up these trials, for they consume an immense quantity of time; but from those made by others, and checked by my own, I have deduced a formula for calculating the expansion at any temperature.

If we consider the force with which matter resists the entrance of heat to be inversely as the square of the distance of its elementary atoms; then, the bulk being as the cube of the distance, the resistance to heat will be inversely as the square of the cube root of the volume, and the increments of expansion by heat directly as the $\frac{3}{2}$ power of the volume. The sum of the increments will, therefore, be as the $\frac{5}{2}$ power of the volume, and the equation must give zero at 40°; hence it will be $A\,(t - 40°)^{\frac{5}{2}}$ = the expansion, where A is a coefficient to be found by experiment, and t denotes the temperature.

The calculation is easy enough by logarithms, for, $\log A + \frac{5}{2} \log (t - 40) = \log$ of the expansion;

$$\text{or } 3\left(\frac{\log \text{expansion} - \log A}{5}\right) = \log (t - 40°).$$

The formula in the last form applies to my experiment, and becomes

$$3\left(\frac{\log \text{expansion} + 3{\cdot}09555}{5}\right) = \text{the log } (t - 40),$$

the expansion at 112° being considered unity; hence the comparison is easy, and is as under.

Expansion.	Temperature by experiment.	Temperature by formula.
1	112°	112°
0·75	104°	100°
0·5	90°	87°
0·25	74°	71°
0·00	40°	40°

The coincidence is as near as we could expect, considering how difficult it is to insure perfect accuracy in the observations; but, before we proceed further in experiment, it is natural to ask how it will agree with others already made.

The expansion of water from 40° to 212° has been found to be 0·04333, its bulk at 40° being unity. By substituting this value in the formula, we find the coefficient A, and have the rule $\frac{5}{2} \log (t - 40) + (-6{\cdot}910909)$, or its equivalent $\frac{5}{2} \log (t - 40) - 5{\cdot}089091 =$ the log of the expansion.

The formula being in this case derived from a probable hypothesis, it is more likely to express the true expansion, than one made out merely to fit a short range of experiments. The absurd conclusions which may follow from an experimental rule are avoided; and that such conclusions do arise out of formulæ made to fit a particular set of experiments, we have an evidence in the case under consideration; for Dr. Young* has given a formula for calculating the expansion of water, which becomes negative

* Lectures on Natural Philosophy, Vol. II. p. 392.

when the temperature is 540°; indicating that water would decrease in bulk, by increasing its temperature above that point; this is a cirumstance too improbable to guide us in any practical application of the fromula.

The annexed Table shows the bulk and expansion for a few temperatures.

Temperature.	The expansion.		Bulk by formula.	Temperature.	Expansion by formula.	Bulk.
	By experiment.	By formula.				
40°	0	0	1·0000	400°	0·1484	1·1484
64°	0·00133	0·00162	1·00159	800°	0·5155	1·5155
102°	0·00760	0·00791	1·00791	1000°	0·7610	1·7610
212°	0·04333	0·04333	1·04333	1171°	1·0000	2·0000

In my own experiments, the formula was in defect in the temperatures between 40° and 112°; here it is in excess; the difference may arise from the expansion of the glass in my trials. According to this formula, water will expand to double its bulk at 40° by a temperature of 1171 degrees. What would be the force of the steam to confine it to the liquid state at that temperature? There is abundant scope for curious research in this matter: it is one where speculative opinion feels the want of experience.

I am not aware of there being any experiments on the expansion of water above the boiling point. When I find an opportunity, I intend continuing the series as I can, using something to color the distilled water, for facility of observing; and I trust soon to be able to communicate some account of my progress.*

* It is not certainly known whether Mr. Tredgold ever followed out the consideration of this interesting subject; but, as he made no further communication thereon to the Institution, and his premature death took place soon after the date of this paper, it seems probable that his experiments were never resumed.

IV. PARTICULARS OF THE CONSTRUCTION OF THE LARY BRIDGE, NEAR PLYMOUTH. BY MR. J. M. RENDEL, CORR. M. INST. C. E.

As this bridge is founded on a shifting sand, in a rapid tideway, and presents some novelties in the design, it is hoped that an account of the methods successfully adopted for laying and securing the foundations, and some particulars of the superstructure, will be acceptable to the members of the Institution.

The Lary, over which this bridge is built, and from which it derives its name, is the estuary of the river Plym, and connected with Plymouth Sound by Catwater. The general width of the estuary is half a mile, but at the site of the bridge the shores abruptly approach each other, and form a strait between 500 and 600 feet wide.—The tide rushes through this strait with a velocity of 3 feet 6 inches a second, and flows on an average 16 feet perpendicular. The depth at low water is from 5 to 6 feet.

By boring it appeared that the bed of the river was sand to the depth of 60 feet—the lofty lime rock on each shore dipping abruptly from high water, and forming a substratum nearly horizontal across the strait. The sand in the wide parts of the estuary above and below the bridge is fine; at the site of the bridge the current leaves only the coarser kind; but this is not sufficient to resist the heavy land floods, to which the Plym is liable, and it frequently happens that the bed of the river is scoured away several feet in depth in winter and refilled in the summer.

When called on by the Earl of Morley, who built this bridge at his sole expense, to prepare a design, I furnished one on the principle of suspension, spanning the whole width of the strait, and having the towers on its rocky shores. Our president* was consulted by his lordship, and the plan being approved of by him, an act was ob-

* The late Mr. Telford

tained in the session of 1823 authorising its erection; but on the commencement of the works, difficulties arose which led to the abandonment of the suspension bridge and the ultimate adoption of the present one of cast iron.

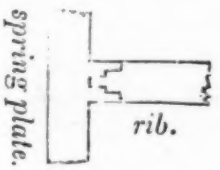
The drawings (see Plates I. and II.) which accompany this paper, will, I trust, give a general idea of the finished structure. The arrangement of the design differs materially from other works of a similar nature: first, in the masonry of the piers finishing at the springing course of the arches; secondly, in the curvilinear form of the piers and abutments; and thirdly, in the employment of elliptical arches. The adoption of these forms for the piers and arches in unison with the plan of finishing the piers above the springing course with cast iron instead of masonry, has, as I had hoped, given a degree of uniform lightness, combined with strength, to the general effect, unobtainable by the usual form of straight sided piers carried to the height of the roadway, with flat segments of a circle for the arches.

Having given these particulars of the situation and design of the work, I will now add some information as to the proportions of the several parts of the structure.

The centre arch is 100 feet span, and rises 14 feet 6 inches; the thickness of the piers, where smallest, being 10 feet. The arches adjoining the centre are 95 feet span each, with a rise of 13 feet 3 inches. The piers taken, as before, are each 9 feet 6 inches thick. The extreme arches are each 8 feet span, and rise 10 feet 6 inches. The abutments are in their smallest dimensions 13 feet thick, forming at the back a strong arch abutting against the return walls to resist the horizontal thrust. The northern abutment forms a considerable projection, which was deemed advisable in consequence of the obliquity of the adjoining wharf below the bridge; as well as to afford the noble proprietor an opportunity of building a toll-house on extra-parochial ground. The ends of the piers are semicircular, having a curvilinear batter on the sides and ends formed with a radius of 35 feet, and extending upwards from the level of high water to the springing course, and downwards to the level of the water at the lowest ebb. The front of the abutments have a corresponding batter.

The parts of the piers and abutments which lie under water at the lowest ebbs, are composed of 2 feet courses of masonry with offsets, as will be better understood by reference to the drawing. (See plates.)

The roadway between the abutments is 24 feet wide, supported by 5 cast iron equidistant ribs. Each rib is 2 feet 6 inches in depth at the springing, and 2 feet at the apex by 2 inches thick, with a top and bottom flange of 6 inches wide by 2 inches thick, and is cast in 5 pieces; their joints, (which are flanged for the purpose,) are connected by screw pins with tie plates equal in length to the width of the roadway, and in depth and thickness to the ribs; between these meeting plates the ribs are connected by strong feathered crosses, or diagonal braces with screw pins passing through their flanges and the main ribs.—The springing plates are 3 inches thick, with raised grooves to receive the ends of the ribs, which have double shoulders, thus:



These plates are sunk flush into the springing course of the piers and abutments, which, with the cordon and springing course, are of granite. The pier standards and spandril fillings are feathered castings, connected transversely by diagonal braces and wrought iron bars passing through cast iron pipes, with bearing shoulders for the several parts to abut against. The roadway bearers are 7 inches in depth by $1\frac{1}{2}$ thick, with a proportional top and bottom flange; they are fastened to the pier standards by screw pins through sliding mortices, whereby a due provision is made for either expansion or contraction of the metal—the roadway plates are $\frac{7}{8}$ of an inch thick by 3 feet wide, connected by flanges and screw pins, and project 1 foot over the outer roadway bearers, thus forming a cornice the whole length of the bridge.

After what has been stated of the character of the river and nature of its bed, it is unnecessary to remark that extreme caution was indispensable in preparing and securing the foundations.

We commenced by driving sheeting piles to a depth of 15 feet around the whole area of the base of the piers and abutments.—These piles are of beech plank, 4 inches thick, having their edge grooved to fit thus :

and were driven in double leading frames fixed to temporary guide piles :—great attention was paid to have them perfectly close. When pitched they were from 16 to 18 feet long, properly hooped and shod with plate iron shoes, weighing on an average 2 lbs. each. These piles were driven with a cast iron weight of 450 lbs. worked by seven or eight men in what is termed a ringing engine. They were driven several feet below low water by means of punches.

As these pilings were carried on, the sand was excavated from the space they enclosed to a depth of 5 or 6 feet below the general level of the river, and from 9 to 10 feet below the level of low water of ordinary tides. These excavations were effected by means of sand spoons of the following construction. Strong canvas bags, capable of containing about 2 cubic feet of sand, were firmly secured to elliptical rings of wrought iron, each ring having a socket to receive a long wooden handle in the direction of its transverse axis, and a swivel handle through its conjugate axis. Stages were fixed on the leading frames in which the sheeting piles were driven, at about 3 feet above low water, and each spoon was worked by three men in the following manner :—a rope was fastened to the loop in the swivel handle of the spoon frame, one end of which was passed over a single block fixed a few feet above the level of the stage, and the other end was held by one of the workmen, whose business it was to pull the spoon when at the bottom towards him, while a second pressed it downwards and guided it, by means of the long wooden handle, till it was thought to be filled ; the third man, who was stationed at the rope which worked through the single block, then hoisted the spoon to the stage and discharged its contents into a shoot, which drained into the river. After the laborers had become used to the work, these operations were carried on with considerable despatch, favorable tides generally affording from 3 to 4 hours' work per day.

As these excavations proceeded, the ground was piled with whole timbers of large Norway and small sized Memel, and as many of beech as could be procured of the desired length ; these piles, being properly shod and hooped, were driven from temporary stages, fixed above high-water level, by weights varying, according to the size of the pile, from 10 to 15 hundred weight ; they were disposed in five rows, in the width of the foundations, from 4 feet to 4 feet 6 inches from centre to centre, and were driven till they did not sink more than one inch with eight blows of the 15 hundred weight driver falling from a height of 25 feet, and then received twenty additional strokes with the same weight and fall.

These piles, none of which were less than 35 feet long, were driven to the level of the stage, and then punched to their proper depth. The punches used for this purpose were made of sound and well seasoned elm, hooped throughout their length, and having at their lower ends a strong cast iron ring, about 18 inches wide ; this ring had a thick partition plate, cast in the middle of its width, which separated the head of the pile from the end of the punch ; the lower end of the ring was cast a little conical, and the pile heads were made to fit it accurately thus,

By this means the pile heads were but little injured, and the loss of momentum occasioned by the intervention of a punch was reduced to a mere trifle.

The next operation was to cut off the bearing piles to their proper depth, and to pave and grout the spaces between them. The usual mode of cofferdams was manifestly inapplicable to such a bed of sand ; I therefore, in an early stage of the works, proposed to the contractors that the pile heads should be levelled, and the spaces between them paved by means of a diving bell. To save expense, this bell was made of wood, and with the necessary machinery was finished and put to work within six weeks from the time it was determined on. With its assistance the works were carried

on with expedition and success. When in operation it contained two men, who, being provided with the necessary instruments for cutting off the piles, paving the spaces between them, &c., continued at work for four hours, when they were relieved by two others.

As much depended on the regularity with which the pile heads were levelled, great care was bestowed on this part of the work. It was accomplished in the following manner:—the four angular piles of each foundation being cut as low as the water would permit, were accurately levelled from a plug on the shore, to ascertain how much each had to be reduced to bring it to its proper level; on each of these piles was marked the portion remaining to be cut by the bell men, which being done, all the remaining piles were levelled from them, by means of a spirit-level, accurately adjusted in a piece of wood, sufficiently long to be applied to three piles at a time. The paving between the pile heads was performed in an equally simple and satisfactory manner.

As this economical bell answered every required purpose, a general description of the whole apparatus may prove acceptable.

The internal dimensions of the bell were 5 feet 6 inches in length, 4 feet 6 inches in width, and 5 feet in height; the sides, ends, and top were made of two thicknesses of 1½ inch well seasoned elm board; the inner case was constructed with its joints parallel to the top and bottom or mouth of the bell, whilst those of the outer one were vertical, or at right angles to the inner joints; the top joints were crossed in the same manner as the sides; all the joints had a slip of flannel, saturated in a composition of bees' wax, laid between them, and were dowelled together and set as close as possible by means of screw clamps, &c., the sides were rabbeted to the end, and the internal angles were strengthened with brackets. The whole surface between the inner and outer case was covered with double flannal, saturated as just described, and was then connected together by a number of wooden pins, dipped in tar and tightly driven; the top was perforated with six holes of 6 inches diameter each, in which was firmly fixed a corresponding number of strong lenses set in white lead; a hole of 3 inches diameter was made in the centre, in which was fixed a brass pipe with a screw to attach the air tube, four hoops of wrought iron, two internal and two external, were screw bolted together through the sides and ends of the bell: internal and external cross lacings were also screw bolted to those hoops, and to the sides and top of the bell. In these lacings, the chains by which the bell was suspended, were fixed in strong iron eyes, which passed through the top of the bell, and were riveted to the inner lacings. All the screw-bolts were driven with tarred oakum, and every precaution was taken to render the whole air-tight. The bell thus finished weighed about 1 ton 10 hundred weight, but it required from 5 to 6½ tons to sink it, and overhaul the ropes by which it was suspended; cast iron plates, from 1¾ to 2 inches in the thickness, were therefore hung externally round its sides and ends, till it was sufficiently loaded to sink with steadiness in about 25 feet of water.

The bell was provided with two movable seats and a foot-board for the divers, and at top long boxes were fixed, in which their tools were kept; it was supplied with air by a double acting force-pump, the cylinders of which were 7 inches diameter in the clear, the pistons making a 14 inch stroke. This pump was generally worked by four men, and made, on an average, according to the depth of water and run of the tide, about eight double strokes per minute.

Around the foundations on which the bell was to be employed, temporary piles were driven, and cut off level about 15 feet above high water, and cross braced; on the top of these piles whole Memel tembers were firmly fixed, care being taken to have the side beams parallel to each other. A strong frame, equal in length to the distance between the parallel beams of the above stage, and about 4 feet wide, mounted on four small cast iron flanged wheels, traversed on an iron railway laid on the beams; this frame was moved on the railway by means of a rope connected to the sides, and worked by two common winches, one fixed at each end of the stage; on the beams of this traverse frame a railway was also laid, on which worked a carriage, mounted in a similar manner, and sufficiently large and strong to carry a purchase machine capable of raising the bell by the labor of four men; the bell was suspended

to this carriage by two treble blocks, the upper block being lashed to one of the cross beams of the frame, and the lower connected to the sling chains of the bell by a strong shackle. This traverse frame was easily moved by winches affixed to the ends of the long frame, over which ropes worked, having their ends made fast to the purchase machine frame.

By these traverse frames the bell was moved with great celerity to any part of the foundations. The machinery required the attendance of six active men, viz. one to each of the four winches, and two to the purchase machine. It was the sole business of a careful man to attend to the signals of the divers, and to direct the men at the machinery and air-pumps accordingly. The signals were communicated by a line, one end of which was fixed in the bell, and the other held by the signal-man, whose place was on the stage. To avoid confusion in the signals, any thing requiring great precision was communicated to either the divers or signal-man by means of a board attached to the line on which either party wrote with chalk, and by these means a regular correspondence could be carried on.

By means of the bell and apparatus, the works proceeded with safety and expedition, and I feel confident that diving-bells may be employed by the bridge builder in a variety of cases with much greater advantage and economy than coffer-dams.

The foundations being prepared, and guides fixed to the plank piles, caissons were floated off from the shore with one, and in some instances two courses of masonry, and sunk. The greatest success attended these operations from the care that was taken to get the foundations perfectly level: of course, the heads of the plank piles were not cut off until the caissons were sunk.

The bottoms of the caissons were made of beech plank and beams; the bottom plank was 4 inches thick and laid in the transverse direction of the pier, across which the beams 12 inches by 8 inches were placed so as to correspond with the rows of piles in the foundation. The spaces between the beams were filled with masonry set in Pozzuolana mortar, and grouted; and a flooring of 3 inch plank, closely jointed and well caulked, so as to be perfectly water-tight, covered the masonry and beams. The top and bottom planks were trenailed to the beams, and the whole strengthened by a strong frame of beech, a foot square, surrounding the bottom and fastened to it by strong screw bolts and trenails.

The upper surfaces of the beams of this frame were grooved to receive a strong tongue, fitting a corresponding groove in the bottom beams of the sides and ends of the caissons, which were made in the usual way, and connected to the bottom by strong lewes irons fitted to cast iron boxes, firmly fixed in the bottom planking. The lewes irons were fixed about 8 feet apart, and were easily removed when the masonry was brought up to the height of the caisson. The introduction of the tongue in the bottom beams of the caisson proved of the greatest utility, as it prevented leaks from the slight sinkage of the bottom between the lewes irons, which it is impossible to prevent when the caisson grounds.

The caissons were furnished with sluices, and made 15 feet high, which gave the masons an opportunity of working about five hours each tide on an average of neaps and springs.

The masonry of the piers and abutments is composed of solid compact limestone, raised in the quarries of the noble proprietor of the bridge* in the adjoining cliffs, and Dartmoor granite, the latter used only, however, in the springing courses and cornices. The limestone is quarried in masses, varying from two to six tons weight, and these were taken to the work on a railroad, continued from the quarries across the river on a stage or temporary bridge, passing close to the piers and abutments, and under the stages on which the diving bell was worked as before described, and the machinery used in working the bell was applied to taking the stone from the wagons, and in setting it. This machinery was found of incalculable advantage in building with such heavy blocks of stone, moving them with ease and the minutest accuracy from over head, and, consequently, without obstructing or incommoding the builders in the caissons.

Experience having taught me that the

* From these quarries the large blocks of stone used in paving the breakwater are taken.

mortar used in the construction of these works is of an excellent quality, I shall, I hope, be excused if I add to this already long paper a few words on this subject.

The blue lyas stone got from the coast of Dorsetshire was burnt at the bridge as the works proceeded, and, whilst hot from the kiln, was ground in a mill to a fine powder. It was then taken to another mill, and in its powdered state mixed with prepared Pozzuolana and sand, and ground until it formed a tough paste, no more water being used than was absolutely necessary. The best mortar, or that used in the bottom courses of the piers and abutments, and for the front work, was composed of one measure of powdered lime, one measure of Pozzuolana, and two measures of sand. The backing mortar was prepared with one measure of lime, half a measure of Pozzuolana, and two measures and a half of sand: the sand was of an excellent quality, got from the site of the bridge.

The following circumstance will sufficiently prove the goodness of this mortar. Some masonry, which had been done in one of the foundations about twelve months, had to be removed, when the stones were found so firmly united, that gunpowder was necessary to separate them.

I have before described the bed of the river to be a loose sand moved by the slightest increase of current, and that this circumstance, together with the difficulty of founding piers and abutments, induced me to propose a suspension bridge spanning the whole width of the river. It was however hoped, when a change of plan became necessary, that the plank piles, with the aid of some stone thrown round them, would be sufficient to meet the increased current occasioned by the bridge; but as the erection of the piers and abutments proceeded, the necessity of a more extended security for the foundations became manifest, as the bed of the river, for its whole width, and to an extent of from 50 to 60 feet above and below the bridge, was gradually scouring away. I therefore proposed to form an artificial bed, to the full extent to which the natural one was removed, with clay from 18 inches to 2 feet thick, and to cover the clay with rubble stone of all sizes from 200 lbs. each downwards. This plan of operation was suggested by observing these materials in vast abundance in the adjoining limestone quarry spoil hills, and after I had submitted the clay to experiment, and found it capable of resisting a current acting immediately upon it at a velocity of 7 feet per second. The clay and stone were deposited with great regularity, giving to the channels under each arch a slight concavity in the middle: the combined thickness of the clay and stone is from 2 feet to 2 feet 6 inches, and just replaces the loss of the natural bed.

By this union of materials an indestructible bed has been produced. The clay shields the natural bed from the current, whilst at the same time it forms a tenacious cement in which the stone buries itself and which is hardened by the volume of water constantly pressing on it. In six months after this work was finished, I ascertained that sea weeds were growing over its surface, and that it was sufficiently firm to resist an oyster dredge.*

Messrs. Johnson of Grosvenor Wharf, London, were contractors for the masonry, &c, and Mr. William Hazledine, of Shrewsbury, for the iron work.

The contract amount for the masonry, &c, was	£13,365 0
The contract amount for the iron	13,761 0
Making the total cost	£27,126 0

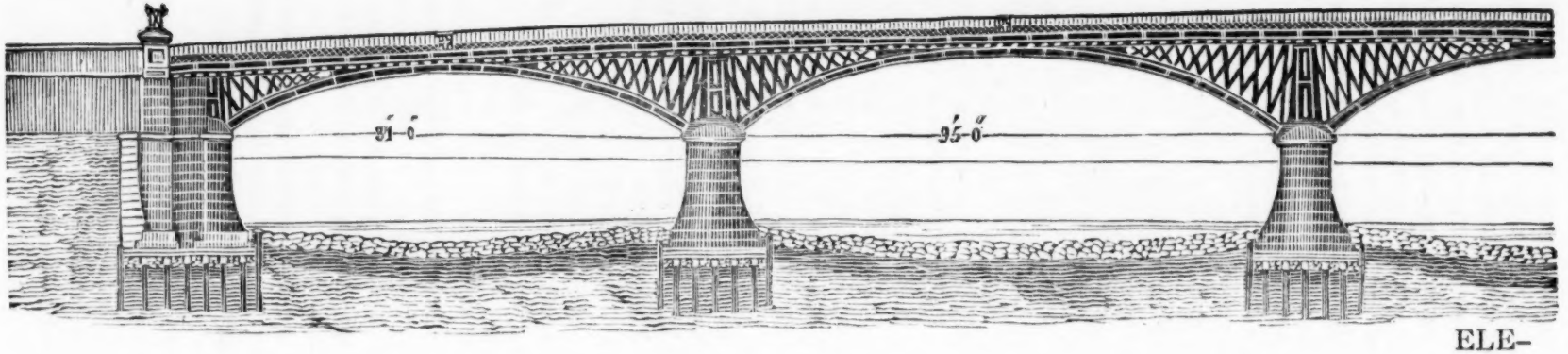
The work commenced in August, 1824, and the Bridge was opened in July, 1827.

* At the present time (1836) the surface is so hard, that heavily laden wagons would not sink in it.

Plate 1.

CAST IRON BRIDGE OVER THE LARY, NEAR PLYMOUTH.

By JAMES M. RENDEL, Civil Engineer.



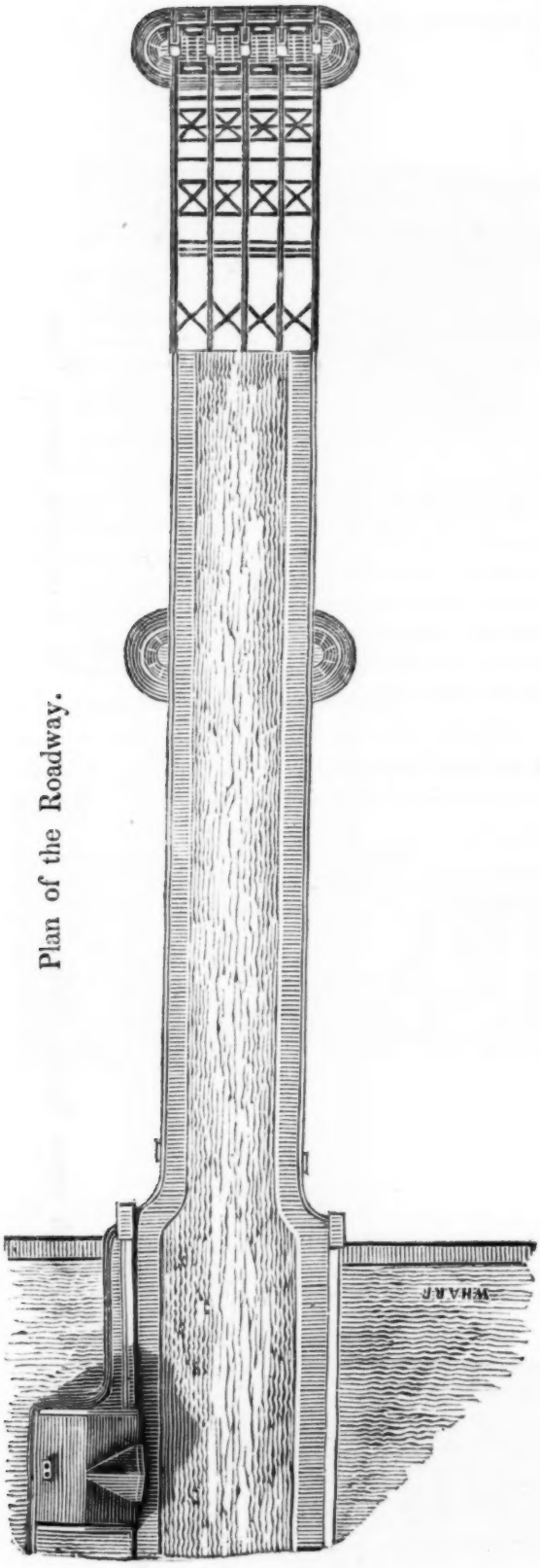
ELE-

VATION.

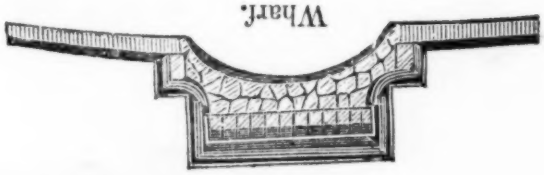
A, High water Spring Tides.

B, Low water Spring Tides.

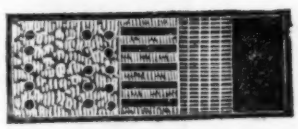
Plate 1.

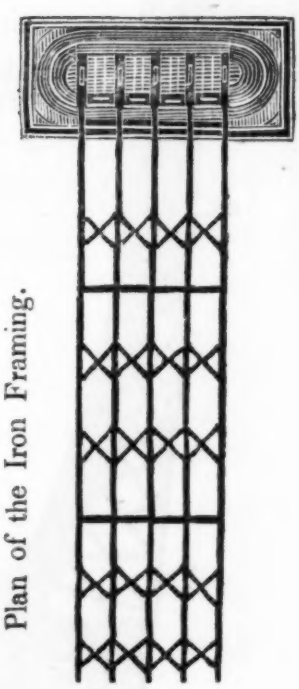


Plan of the Roadway.



Plan of the Foundation.



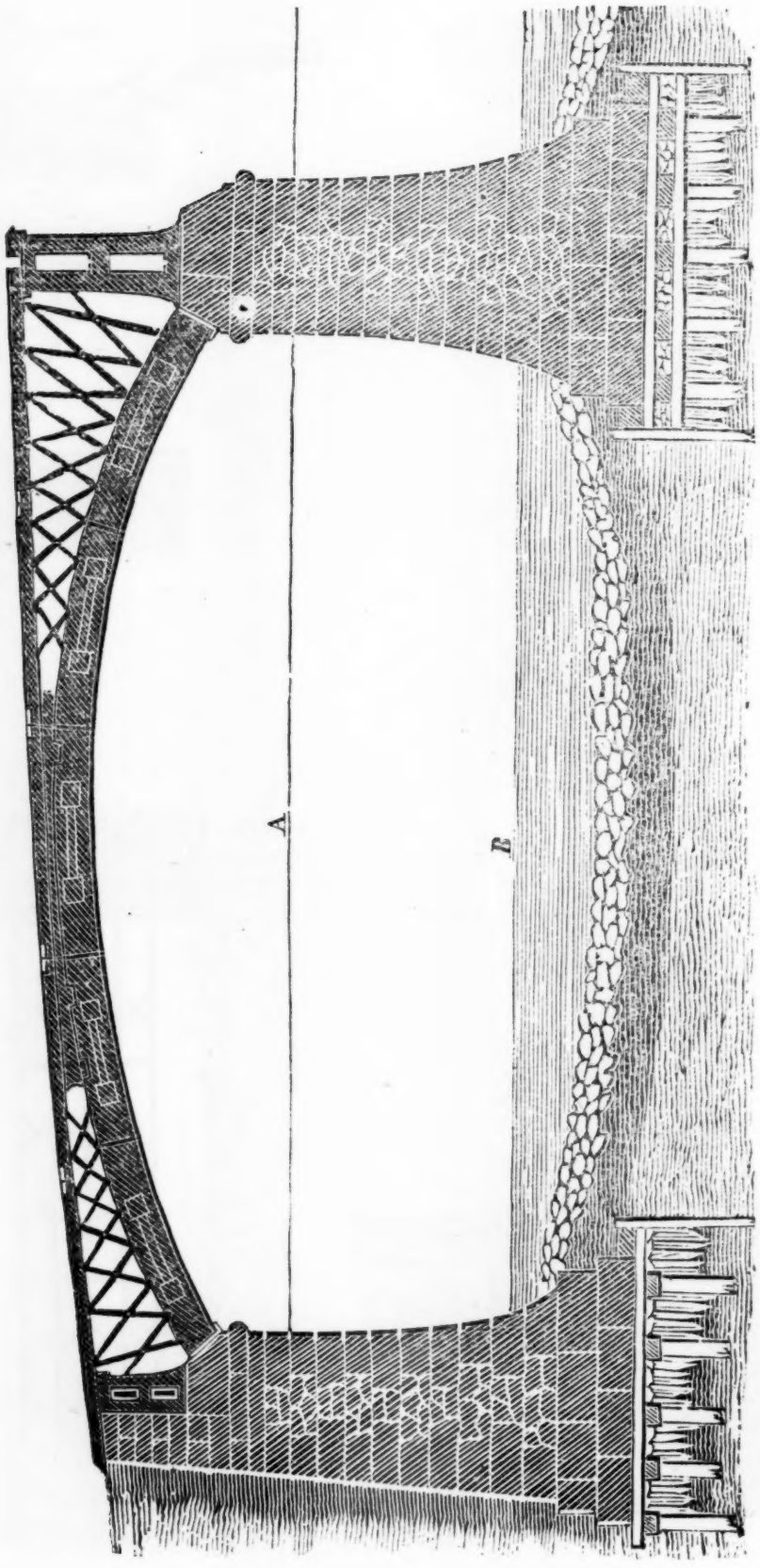


Plan of the Iron Framing.

Plate 2.

LARY CAST IRON BRIDGE.

Longitudinal Section of one of the Side Arches.



A, High water Spring Tides.

B, Low water Spring Tides.

Plate 2.

Section through centre of Arch.

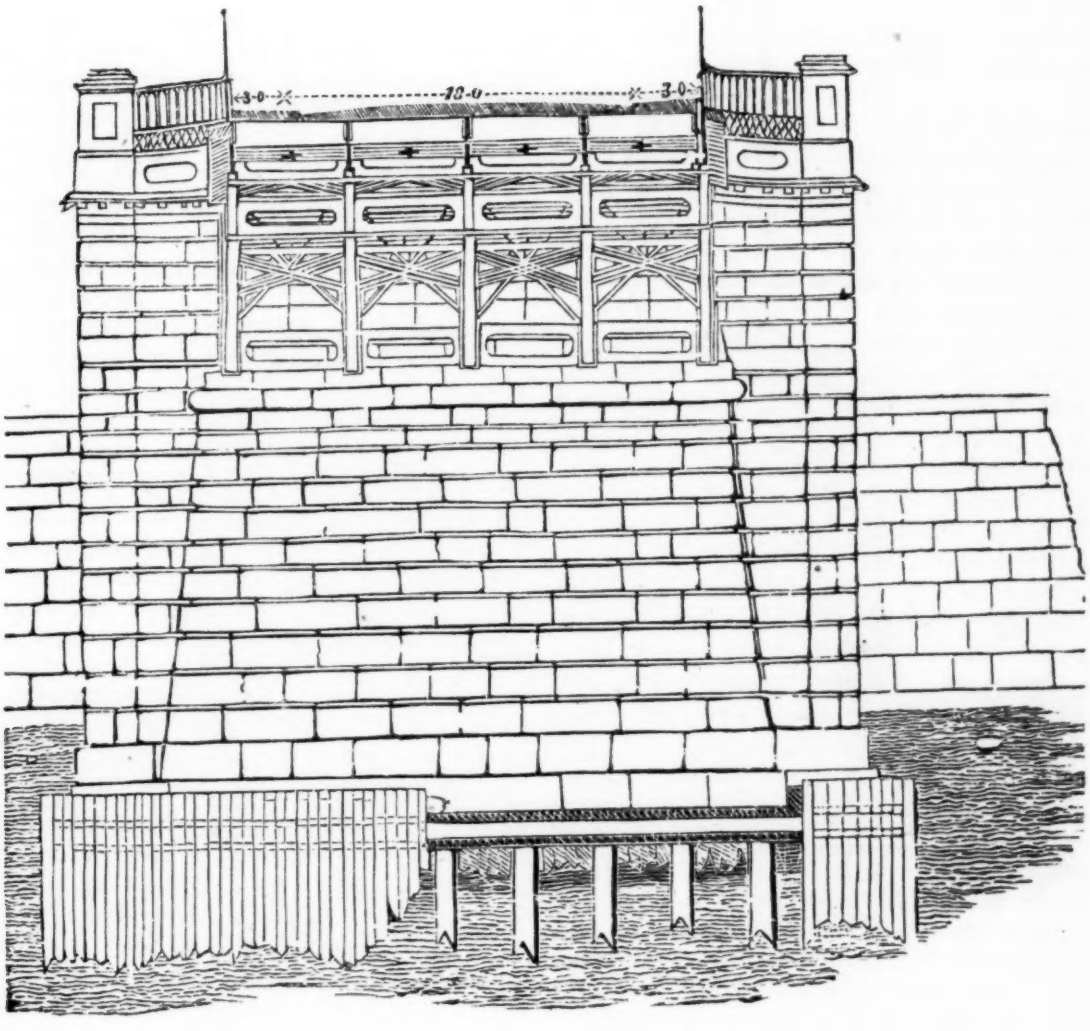
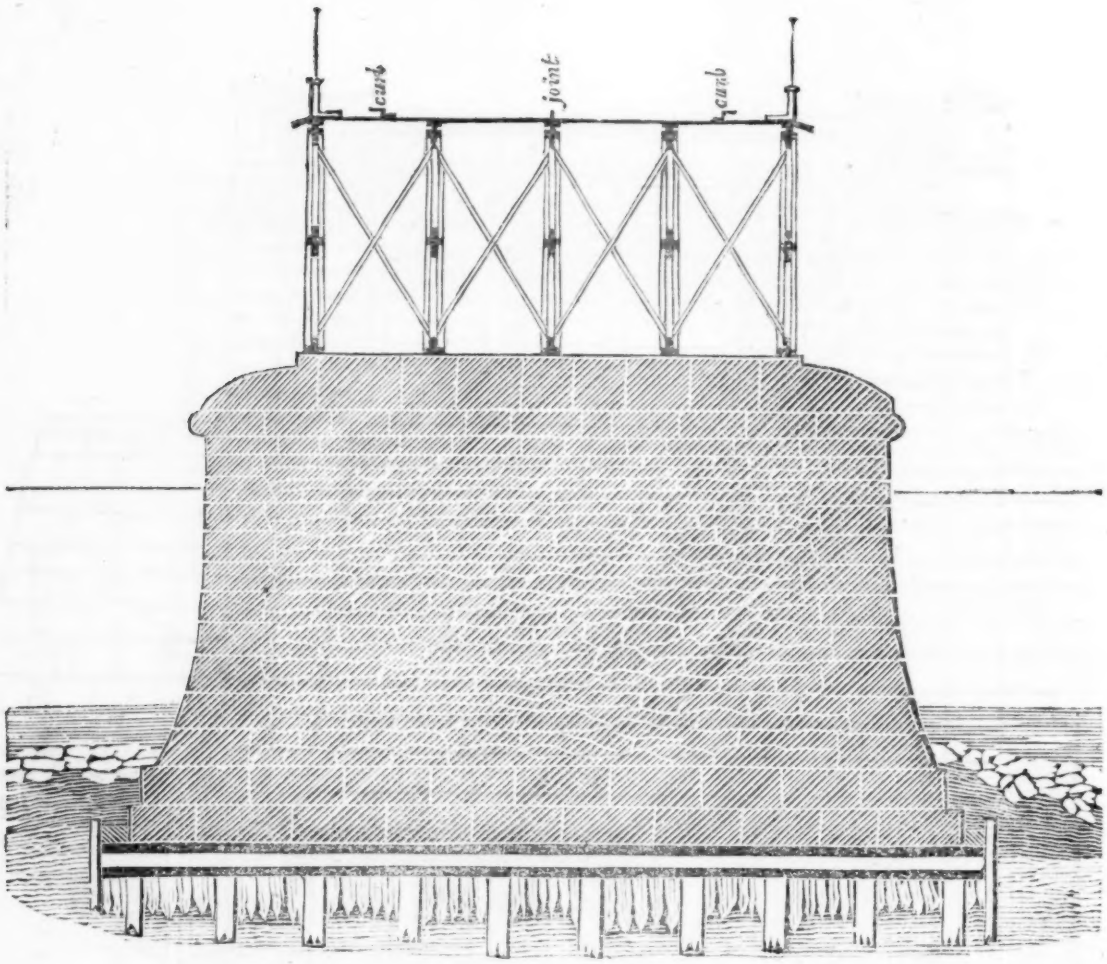


Plate 2.

Section through centre of Pier.



V. ON THE HOT AIR BLAST. BY MR. J. B. NEILSON, COR. MEM. INST. C. E. COMMUNICATED IN A LETTER TO THE LATE PRESIDENT, THOMAS TELFORD, Esq.*

I feel much pleasure in being able to comply with your request in mentioning to you what I conceive to be the nature of the advantages likely to be derived by the Iron Trade, and the country generally, from my invention of the Hot Blast, and at the same time, I shall very willingly state the circumstances, agreeably to your request, which, in the first instance, led me to direct my attention to the improvement of the process of iron-making.

About seven years ago, an iron-maker, well known in this neighborhood, asked me if I thought it possible to purify the air blown into blast furnaces, in a manner similar to that in which carburetted hydrogen gas is purified; and from this gentleman's conversation, I perceived that he imagined the presence of sulphur in the air to be the cause of blast furnaces working irregularly, and making bad iron in the summer months. Subsequently to this conversation, which had in some measure directed my thoughts to the subject of blast furnaces, I received information that one of the Muirkirk iron furnaces, situated at a considerable distance from the engine, did not work so well as the others; which led me to conjecture that the friction of the air, in passing along the pipe, prevented an equal volume of the air getting to the distant furnace, as to the one which was situated close by the engine. I at once came to the conclusion that by heating the air at the distant furnace, I should increase its volume in the ratio of the known law, that air and gases expand as 448 + temperature.

Example.—If 1000 cubic feet, say at 50° of Fahrenheit, were pressed by the engine in a given time, and heated to 600° of Fahrenheit, it would then be increased in volume to 2104·4, and so on for very thousand feet that would be blown into the furnace. In prosecuting the experiments which this idea suggested, circumstances however became apparent to me, which induced the belief on my part, that heating the air introduced for supporting combustion into air furnaces, materially increased its efficiency in this respect; and with the view of putting my suspicions on this point to the test, I instituted the following experiments.

To the nozzle of a pair of common smith's bellows, I attached a cast iron vessel heated from beneath, in the manner of a retort for generating gas, and to this vessel, the blow-pipe by which the forge or furnace was blown, was also attached. The air from the bellows having thus to pass through the heated vessel above mentioned, was consequently heated to a high temperature before it entered the forge fire, and the result produced, in increasing the intensity of the heat in the furnace, was far beyond my expectation, and so evident as to make apparent to me the fallacy of the generally received opinion, that the coldness of the air of the atmosphere in the winter months, was the cause of the best iron being then produced.

In overthrowing the old theory, I had however established new principles and facts in the process of iron-making, and by the advice and assistance of Charles M'Intosh, Esq., of Crossbasket, I applied for and obtained a patent, as the reward of my discovery and improvements.

Experiments on the large scale to reduce iron ore in a founder's cupola, were forthwith commenced at the Clyde Iron Works, belonging to Colin Dunlop, Esq., which experiments were completely successful, and in consequence, the invention was immediately adopted at the Calder Iron Works, the property of William Dixon, Esq.; where the blast being made to pass through two retorts placed on each side of one of the large furnaces, before entering the furnace, effected an instantaneous change, both in the quantity and quality of iron produced, and a considerable saving of fuel.

The whole of the furnaces at Calder and Clyde Iron Works were in consequence immediately filled up on the principle of the Hot Blast, and its use at these works continues to be attended with the utmost success; it has also been adopted at Wilsontown and Gartshirrie Iron Works in Scotland, and at several works in England and France, in which latter country I have also obtained a patent.

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* Although the application of heated air has been extended, and the subject tereated more at large since this paper was written, the detail of the discovery from Mr. Neilson to the late President, cannot fail to be interesting. In a future volume, the Council trust to be able to add a further communication from that gentleman on the subject.

The air as at first raised to 250° of Fahrenheit, produced a saving of three-sevenths in every ton of pig-iron made, and the heating apparatus having since been enlarged, so as to increase the temperature of the blast to 600° Fahrenheit and upwards, a proportional saving of fuel is effected; and an immense additional saving is also acquired by the use of raw coal instead of Coke, which may now be adopted. By thus increasing the heat of the blast, the whole waste incurred in burning the coal into coke is avoided in the process of iron-making.

By the use of this invention, with three-sevenths of the fuel which he formerly employed in the cold air process, the iron-maker is now enabled to make one-third more iron of a superir quality

Were the Hot Blast generally adopted, the saving to the country in the article of coal, would be immense. In Britain, about 700,000 tons of iron are made annually of which 50,000 tons only are produced in Scotland; on these 50,000 tons, my invention would save in the process of manufacture, 200,000 tons of coal annually. In England, the saving would be in proportion to the strength and quality of the coal, and cannot be computed at less than 1,520,000 tons annually; and taking the price of coals at the low rate of four shillings per ton, a yearly saving of £ 296,000 sterling would be effected.

Nor are the advantages of this invention solely confined to iron-making: by its use the founder can cast into roods an equal quantity of iron, in much less time, and with a saving of nearly half the fuel employed in the cold air process; and the blacksmith can produce in the same time one-third more work, with much less fuel than he formerly required.

In all the processes of metallurgical science, it will be of the utmost importance in reducing the ores to a metallic state.

VI. AN APPROXIMATIVE RULE FOR CALCULATING THE VELOCITY WITH WHICH A STEAM VESSEL WILL BE IMPELLED THROUGH STILL WATER, BY THE EXERTION OF A GIVEN AMOUNT OF MECHANICAL POWER, OR FORCIBLE MOTION, BY MARINE STEAM ENGINES. COMMUNICATED BY MR. FAREY, M. INST. C. E.

Notwithstanding the great experience which has been acquired in constructing steam vessels, few engineers possess any rule for determining *a priori*, what will be the speed of a new vessel, which is designed.

The usual course is, to institute a comparison with some former steam vessel, whereof the dimensions and performance is known, and by estimating all the differences of dimensions between that former vessel, and the new-intended one, the difference of its expected performance from the known performance, is inferred. When the new intended vessel is not materially different from some previously known case, this method of comparison answers the purpose; but so many cases arise in practice, which are not comparable with any known case, that a general rule is greatly wanted, and the writer of this communication has kept the subject in view, from the first establishment of steam vessels till the present time, omitting no opportunity of ascertaining and recording the performance of every steam vessel whereof the form and dimensions could be ascertained, and at intervals arranging the observations in classes, and deducing rules from them, which have been amended and improved from time to time, as more complete information was attained.

Almost all experiments which have been made, on the resistance of drawing floating bodies, along the surface of unconfined, but tranquil water show, that the resistance increases as the square of the velocity; and hence it may be inferred, that if the draft, or direct pull, (such as horses exert on the towing line of a canal boat,) which is requisite to draw a vessel along the water at a rate of five miles per hour, is one ton, then to draw it at the rate of ten miles per hour, will require a pull of four tons.

It follows as a consequence, that the exertion of mechanical power, or forcible motion, must progress according to the cubes of the velocities, because an increased force is to be exerted with an equally increased velocity; for instance, if an exertion of 25 horse power will impel a given vessel at the rate of five miles per hour, it would require an exertion of 200 horse power, to impel the same vessel at the rate of ten miles per hour.

These two propositions are to be considered as assumptions, when applied to

steam vessels, because the experiments on which the first is founded, viz., the rate of resistance being as the square of the velocity, have been all made on very small vessels, nevertheless they all concur in very nearly the same result*; and again, in steamboats, the water yields very considerably to the paddles, and a loss of power is thereby occasioned,† which is not contemplated in framing the second proposition, (viz. that the power exerted must be as the cube of the velocity, because the resistance of draft is as the square of the velocity.)

Notwithstanding any doubts which may be entertained of the exactitude of the last proposition, the following rule (which proceeds on the assumption, that the impelling power which must be exerted, is as the cube of the velocity) will be found to give results which approximate to the actual performance of steam vessels in common use.

The rule contemplates the extent of surface which the bottom of the vessel exposes to contact with the water, and also the sectional area of the water which must be divided by the vessel, in advancing forwards; and numbers representing those two quantities, are combined into one sum, which is taken to represent the resistance of the vessel, compared with any other vessel of

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* A fund of valuable information on this subject is contained in the papers of the late Colonel Beaufoy. Since the above was written, those papers have been published by his son in a quarto volume, which has been distributed in the scientific world; a copy is preserved in the library of the Institution.

† This loss had formerly a much greater influence than at present; because the improvements which have been made in proportioning the paddles of modern steam boats, has rendered the loss less considerable. I was formerly induced to suppose that the exertion of power increased by a higher ratio than the cubes of the velocities attained by the exertion. This notion arose in the course of some of my earliest deductions, from observations on the steamboats first used in Scotland; comparing their increase of speed with the power exerted by successive engines, of greater and greater magnitude, which were substituted one after another on board the same boats, it appeared that the exertion of power required to produce different velocities, corresponded to some intermediate stage between the cubes and the biquadrates of those velocities; an arithmetical mean between the cube and the biquadrate seemed nearly to correspond to those observations, but subsequently it was found out, that the loss occasioned by the yielding of the water to the paddles, had been very greatly increased when larger engines had been first substituted for smaller engines, but when larger paddle wheels, and paddles, were given to the larger engines, the speed was improved, and when so improved the power exerted came out nearly as the cubes of the velocities.

This notion would be no more worthy of being recorded than a multitude of other attempts to deduce rules from uncomparable observations, if a rumor of it had not, unknown to me, found its way into a memoire upon navigation by steam, read before the institution at Paris in 1826, by M. Seguin, who relates that he consulted me, when I resided at Leeds, and that I considered the resistance of vessels to be proportional to the fifth powers, divided by the cubes of the velocities, which Mr. Seguin says confirmed some opinions of his own.

Now the fifth power of any number being divided by the cube thereof, is only the same as the square of the number, and that is the proportion of force of draft, which I have always assumed to be requisite for overcoming the resistance of pulling a vessel through the water, with different velocities; but the mechanical power, or forcible motion, which must be exerted by a steam engine, in order to overcome that resistance, I assume to be as the cubes of those velocities; I explained to Mr. Seguin, that formerly I had supposed it to be a more rapid rate of increase than the cubes, something like an arithmetical mean between the cube and the biquadrate as above stated. The fifth power divided by the cube, was a statement made to me, and to which I assented, as giving correct results for the resistance of draft; but it is a needlessly complicated mode of expressing the square of a number. J. F.

a different magnitude, but similar in form, the speed in both cases being equal.

In estimating the power exerted by the engines, the rule supposes the actual power, as shown by the indicator, with due allowance for friction, not the nominal power by which the engines are rated, which in modern engines is always very much less than the power actually exerted. For instance, Messrs. Boulton, Watt, and Co.'s marine engines, are calculated to exert about $7\frac{3}{10}$ lbs. effective force, for each square inch of their pistons, and the motion of the pistons in their cylinders causes an expenditure of $31\frac{4}{10}$ cubic feet of steam per minute, for every nominal horse power,* being a little different from their scale for land engines.

Messrs. Boulton, Watt, and Co.'s 50 horse marine engines, have cylinders $39\frac{1}{2}$ inches diameter, their pistons moving $3\frac{1}{2}$ feet stroke, and are calculated to make $26\frac{1}{2}$ strokes per minute. Their 80 horse marine engines, have cylinders $47\frac{1}{2}$ inches diameter, pistons $4\frac{1}{2}$ feet stroke, and calculated at $22\frac{1}{2}$ strokes per minute.

When a trial of any modern marine engine is made by an indicator, the effective or unbalanced pressure of steam, by which the piston is impelled, will be found much more than the assumed $7\frac{3}{10}$ lbs. per square inch, after allowing amply for friction; $11\frac{1}{2}$ lbs. per square inch is probably nearer to an average of good engines; but the very best are considerably more, even as much as $12\frac{1}{2}$ lbs. per square inch. The actual power exerted, will be greater than the nominal horse power, in proportion as the actual force exerted by the piston is greater than the assumed standard of $7\frac{3}{10}$ lbs. per square inch.

The approximate rule is as follows:—

I. Find the area of the transverse section of the vessel, under water, in square feet; extract the square root of that number of square feet; multiply the root by the length of the vessel at the water's surface, and divide the product by the greatest breadth of the vessel at the water's surface; then add the quotient to the above number of square feet; the sum is to be taken for a representation of the resistance of the vessel, compared with others of different sizes, but similar in form, the comparison being made, by the above mode of computation, when they are proceeding with the same velocity.

II. Find the number of horse powers actually exerted by the engines, according to observations made by the indicator, and multiply that number by 1000, in case of vessels of an ordinary form, such as were usually built for sea-going vessels seven years ago*; divide the product by the number previously found as above; then extract the cube root of the quotient; and that root will be near to the velocity of the vessel, in miles per hour, through still water.

Example, of a large vessel, 150 feet long, 27 feet broad, drawing $9\frac{1}{2}$ feet water, impelled by two engines rated at 80 horse power each; she went $9\frac{7}{10}$ miles per hour (in 1826).

The sectional area of the part under water, was 207.6 square feet; the square root of that is 14.4, which multiplied by 150 feet long, and the product divided by 27 feet broad, gives 80 for a representation of the surface of the bottom in contact with the water, and that added to 207.6 square feet, gives 287.6 to represent resistance. The engines were found by the indicator, to exert an effective force of $11\frac{1}{2}$ lbs. per square inch of their pistons, (friction being allowed for,) when they made 23 strokes per minute, of $4\frac{1}{2}$ feet; the pistons being $47\frac{1}{2}$ inches diameter; that is, 128 horse power, actually exerted by each engine, or 256 horse power by both, this being multiplied by 1000, gives 256,000, which product divided by 287.6 gives 890; and the cube root thereof is 9.62 miles per hour, instead of 9.7 miles, as observed.

Another example, of a small vessel, 105 feet long, $17\frac{1}{2}$ feet broad, drawing $5\frac{1}{4}$ feet of water, impelled by one engine, rated at 50 horse power; she went $9\frac{2}{3}$ miles per hour (in 1829.)

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* That horse power being in all cases, according to Mr. Watt's standard, a force of 33,000 lbs. acting through a space of one foot per minute.

* For the very full built forms, such as were used for the early steam boats, built more than 14 years ago, the multipliers should be only 900; or for the very sharp improved forms built in the last two or three years, 1100.

The sectional area was 62 square feet: square root thereof 7.87 × 105 feet long ÷ 17½ feet broad = 47.25, to be added to 62, making 109.25 to represent resistance. The piston, according to the indicator exerted 12½ lbs. per square inch effective force, (after allowing for friction,) and made 30 strokes per minute of 3½ feet, piston 39½ inches diameter, that is, an exertion o 97½ horse power; multiply that by 1000, and divide by 109.25, gives 892, the cube root of which is 9.626 miles per hour.

The above two vessels being the same in speed, but very different in magnitude, the accordance of the results given by the rule with the facts, shows that the rule makes a proper allowance for difference of magnitude.

Another example, of a small boat, 72 feet long, 15 feet broad, a very full built form, impelled slowly, by one engine of the oldest construction, called 10 horse power, made in Scotland, 1814.

Sectional area 42 square feet; square root thereof 6.48 × 72 feet long ÷ 15 feet broad = 31.1, to be added to 42, making 73.1 to represent resistance. The engine was very inferior to the modern ones*, and probably did not exert above 7½ lbs. per square inch of the piston, which was 22 inches diameter, 2 feet stroke, and made 32 strokes per minute, that would be 11.1 horse power. The form of this old boat being very round at the bows, and more resisting than the modern vessels, should have a lower multiplier, viz. 900 instead of 1600; therefore 11.1 horse power × 900 ÷ 73.1 resistance, gives 136.7; the cube root of which is 5 15 miles per hour, which was very near the real speed of this boat.

Another example, of an old boat, 156 feet long, 33 feet broad, in America, 1816, impelled by one engine, piston 40 inches diameter, 5 feet stroke, 17 strokes per minute, she went 6½ miles per hour. Sectional area 150 square feet; square root 12.25 × 156 ÷ 33 = 57.9 to be added to 150 = 207.9 for resistance; the piston probably exerted about 9½ lbs. per square inch, which would be 61.5 horse power*. The form of this boat being very full, multiply by 900 and divide by 207.8 = 266.5, the cube root of which gives 6.43 miles per hour.

Another example, of a small boat, 85 feet length, 18½ feet wide, 3¾ feet draft of water, impelled by two engines, pistons 22 inches diameter, 2½ feet stroke, 34 strokes per minute (in 1818) Sectional area 62 square feet; square root thereof 7.87 × 85 feet length ÷ 18½ feet wide = 36, which, added to 62, gives 98 to represent resistance. The engines were the earliest construction of combined engines, and probably their pistons did not exert above 7¾ lbs. per square inch*; which would be 30.3 horse power. The boat was sharper than those of the older construction, being very similar in form to those before calculated with 1000 for a multiplier, which being used and ÷ 98 resistance, gives 309, the cube root of which is 6.76 miles per hour. The boat actually went 6¾ miles per hour.

Another example, of a large vessel, 136 feet long, 26 feet wide, 12½ feet draft of water. Impelled by two engines rated at 60 horse power each, she went 8½ miles per hour, 1825. Sectional area 227 square feet; square root 15.07 × 136 ÷ 26 = 78.8 to be added to 227, making 305.8 to represent resistance. The pistons 43 inches diameter, 4 feet stroke, 26 strokes per minute, exerting 11¾ lbs per square inch, which is 107½ horse power by each, or 215 horse power exerted by both engines. The form of the vessel was full, such as requires 900 for a multiplier; and 215 horse power × 900 ÷ 305.8 gives 633; the cube root of which is 8.59 miles per hour.

The above examples show that the rule applies to cases where the difference of speed is very considerable, as well as the difference of magnitude.

25th April, 1833.

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* In those older examples previous to 1819, wherein no indicator observations were made upon the engines, the probable force exerted by the pistons, has been inferred from indicator observations, made since, upon other engines of similar structure and proportions of their parts.

VII. ON THE EFFECTIVE POWER OF THE HIGH-PRESSURE EXPANSIVE CONDENSING STEAM ENGINES COMMONLY IN USE IN CORNISH MINES. BY MR. T. WICKSTEED, CIVIL ENGINEER. COMMUNICATED IN A LETTER TO THE PRESIDENT.

At your request I beg leave to forward

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* Vide note, p. 115.

you some observations upon Cornish engines, which, although not entering into the detail you seem desirous of obtaining, will not, I trust, be quite devoid of interest.

Having received instructions from the Court of Directors of the East London Water Works to visit the mines in Cornwall, for the purpose of making inquires about the Cornish engines, I left London upon the 1st of August last, and returned upon the 20th of the same month.

My friends, Mr. John Taylor and Mr. Grout, kindly gave me letters of introduction, which enabled me to see any engine I was desirous of viewing.

The first mines I visited were the Wheel Friendship copper mines, near Tavistock, Devonshire, and the Redmoor and Holmbush copper, and the Wheel Brothers silver, mines, near Callington, Cornwall. At the Redmoor mine I saw an engine with a 50 inch cylinder, erected by Messrs. Petherick and West. The mine had not been long at work; the shaft was not more than 156 feet deep; there were two shafts with pumps in, and one was about 560 yards distant from the engine; the motion was communicated by means of horizontal bars, suspended by pendulum rods. The engine was working about two strokes per minute throughout the 24 hours; the work done was light, probably not equal to more than five horses' power; it consumed only three and one-third imperial bushels of coals per 24 hours. The engine had been worked the previous fortnight with turf cut off the neighboring moor, at a cost of eight-pence halfpenny per 24 hours; it required 18 feet square of turf, about 2 inches thick, to keep the steam up for that time. I mention this to show that when a large engine is erected to clear a mine, although in the first instance the work it has to do is not proportioned to its size, nevertheless, the consumption of fuel is nearly in proportion to the work done.

As regards the use of turf, it is evident, as these boilers were constructed with the intention of using coal as fuel, when the depth of the mine and the quantity of water increased, that turf could not be used without an alteration in the fire-places, the bulk of turf required being much greater than that of coal. Mr. Grout has since informed me, that he has ordered an engine and boilers for one of his mines, and that the boilers are to be constructed with a view to the use of turf only.

The next engine that I saw was one at the Fowey Consolidated mines, near St. Blazey. The cylinder was 80 inches, the pump stroke 9¼ feet, the duty was, in August, equal to 83,296,000 lbs., raised 1 foot high, with an imperial bushel, or 84 pounds of coals; it consumed about a bushel or 84 pounds of coal per hour. This is a most splendid engine, and does greater "duty" than any other engine in Cornwall; the construction of the valves and other parts of the engine is so perfect, that although its load was equal to about 51,000 lbs., the hand-gear might be worked by a boy of ten years of age, as far as strength was required; I worked it myself with perfect ease; whereas, although the load upon one of our engines of 36 inches cylinder is only about 12,000 lbs., it repuires not only a strong, but also a weighty man to work it.

The hand-gear is all bright work, and finished in first rate style. The quantity of bright work in an engine of course depends upon the taste of the person ordering it, and I certainly saw many Cornish engines of longer standing than the one in question, that displayed very little bright work; but that it can be executed as well in Cornwall as in any other county in England must appear evident to those who have seen this engine, and the founderies or engine manufactories at Hayle. At the latter place I saw an 80 inch cylinder, 12 feet long, in the boring machine, and could not perceive a flaw in it.

I was very much struck with the ease with which the engine in question appeared to work; there was scarcely any noise, the greatest was that of the steam in its passage through the expansive valve. To one who had been used to the noise of the pumping engines in London, it appeared remarkable.

The reason that this engine does more work than any other in Cornwall is, in my opinion, owing chiefly to the construction of the boilers, which are different to the generality, inasmuch as they have an internal tube, of about 21 inches diameter, passing through the main flue of the boiler, extending from the back part of the boiler as

far as the bridge of the fire-place, dividing the flame as it passes from the fire-place, and thus where the heat is most intense the surface exposed to its action is greatest; there is also a tube of about the same diameter, and 36 feet long, around which the flue from the boilers passes before entering the chimney; into this tube the feed is sent before it passes into the boilers, and is previously heated to a temperature of 180° by means of the heat that might otherwise pass into the chimney unused.

The engines that I next viewed were the following: viz.

50 inch cylinder		at Charleston,	Near St. Austel.
76	Ditto	at East Cremnis,	
66	Ditto	at Polgooth,	
85	Ditto	at the Consolidated Mines,	Near St. Day.
80	Ditto	at Ditto,	
30	Ditto	at United Mines,	

Although all of these engines were good ones, they were not equal to the Fowey Consols; as regards the last, viz. the 30 inch cylinder, the water that is raised out of the mine by this engine is conveyed by a pipe above ground to suppy a water-wheel; and, although it is small and not of modern construction, it is doing nearly twice the "*duty*" of the London pumping engines of 4 times greater area in the cylinder. I mention this engine particularly, because it is doing precisely the same work that a water-works engine has to do in lifting water into a reservoir.

I afterwards viewed the following engines: viz.

Two 80 inch cylinders		at Wheel Vor, near Helston.	
One 90	Ditto	at North Roskear, near Redruth.	
60	Ditto	at South Roskear, near Redruth.	
80	Ditto	at Wheel Darlington, near Marazion.	
30	Ditto	at Wheel Providence, near St. Ive's.	

The 30 inch cylinder at the United Mines, the 80 inch cylinder at Wheel Darlington, and the 30 inch cylinder at Wheel Providence, were raising the water out of the shafts to the *surface*, and I had therefore an opportunity of seeing it thrown up, and I observed that in every case there were no bubbles of air mixed with the water, proving that the pumps were lifting "solid" water, (as it is termed in Cornwall,) and not partly water, and partly air, as had been suggested by those who have no faith in the reports of the work done by the Cornish engines.

The foregoing, with the exception of the engine at Wheel Jewel Mines, near St. Day, which was not at work while I wss there, were all the engines that I saw. And before I proceed to make any further remarks upon them, I beg to call your attention to the Table* that accompanies this Report, which gives further particulars of them, extracted from the "Monthly Reports."

As the accuracy of these Reports has been questioned, or to use plainer language, as it has been asserted that they are false, and that the Cornish engines do not perform the work stated, it may be as well to explain how these reports are made.

When the agents of a mine wish the "duty" of their engines to be published, an accurate measurement of the lifts is made and the diameter of the pumps, and other particulars, are recorded; a counter is fixed upon the engines by Capt. Thomas Lean, (the gentleman who had been appointed by the proprietors of the mines to take an account of the work of their engines,) and this counter has a Bramah's lock attached to it, the key of which he keeps. He visits each of the mines once per month, and takes an account of the strokes made by the engines during the preceeding month. In some instances there is another counter attached to the engine, which is open to the inspection of the engineer, agents, and engine-keepers.

The coals are supplied by a distinct party, who has to account to the agent of the mines for the coals consumed per month; the engine-keepers write orders for the coals they require, and at the end of the month the quantity of coals on hand is measured and deducted; the orders are considered as vouchers, which, after having been examined and countersigned by Capt. Thomas Lean, are passed. It is obviously the interest of the coal agent not to report a less quantity than actually is consumed, being accountable for the quantity used;

* This "Table of the work performed, &c., in January, 1835," is omitted.

he cannot therefore be supposed to combine with the engine keepers, whose object, if dishonest, would be to report a less quantity.

But supposing, for the sake of argument, that the engineers, and the agents of mine, were so disposed, and could get these gentlemen to combine with them for the purpose of making a false report, the insanity of such a proceeding will, I think, appear evident upon a perusal of the following statement.

The engines in Cornwall are designed, the drawings made, and the construction and erection of the machinery superintended, by gentlemen who are appointed as engineers to look after the machinery of the mines. The castings are made, and the work designed by the said engineers is executed, at two large "foundries," or engine manufactories, at Hayle.

There are more than twenty engineeers employed in the mines in Cornwall, all of whom are anxious to construct the best engine, as the parties producing the engines that do the best duty, obtain, of course, the most employment. It is therefore a matter of jealous attention on the part of these gentlemen to take care that no engine shall have undue credit for doing the most work. It happens occasionally, where a great improvement has been made, that doubts are expressed as to the accuracy of the reported duty: in such cases the engineers and agents of the other mines call upon the parties whose engine is reported as performing extraordinary duty to allow them to prove it; this call is answered by fixing a time for the trial—the trial lasts for two or three days, during which time the engine is in the hands of the rival parties, who are on the watch to detect unfair play, if any should be attempted. If the result of this trial is favorable, the party in question receives due credit; if otherwise, his character as an honest man is lost. If this is not as severe a test of the accuracy of the reports as can be made, and not sufficient, then indeed prejudice must have its full swing, and no farther *proof* can be given, as gentlemen going into Cornwall from London and elsewhere, for the purpose of proving the truth of the statement made by the Cornish engineers, may with equal justice be charged with making false reports.

The reported "duty" is not necessarily the whole performance of the engine, the amount of which cannot always be obtained; it is, in fact, merely the weight of water lifted, multiplied by the height in feet to which it is raised, reduced to the number of pounds avoirdupoise raised one foot high, for every bushel of coals consumed, without reference to *friction*. Now as the friction of each engine, and the machinery worked by it, varies,—and as, although this friction has to be overcome, the amount of it is not reported, so the reported duty is not the whole performance of the engine: and, consequently, an engine which is reported as performing certain duty may, in fact, be doing as much work as another engine whose *reported* duty is greater.

The pumps in the mines in Cornwall are worked, and the water raised, as the engine goes "out of doors," the force of the steam is employed to raise the heavy pump rods; these rods are in many instances so weighty that without counterbalances, or, as they are termed in the country, "balance bobs," the engine would not be sufficiently powerful to raise them—for instance, in some cases the pump rods are 150 tons in weight, which is equal to 336,000 lbs. Now the greatest load upon any engine reported in September last, was under 100,000 lbs. It is therefore necessary to have "balance bobs," or beams, one end of which is connected by a rod to the pump rod, and the other is weighted with iron as a counterbalance. These beams are in many instances as large as the beam of a 100 horse Boulton and Watt engine; it is evident that these cannot be worked without friction. In other cases the same engine not only works the pump rods that are in the shaft immediately under the end of the engine beam, but also the pumps in distant shafts, by means of horizontal rods extending in some instances half a mile. These rods are supported either by pendulum rods or work on friction wheels; in these cases the friction must be great. It must also be borne in mind that there is more friction in a small cylinder, in proportion to its area, than in a large one, and, in fact, in all the bearings and working parts of the engine,—the power increasing as the squares of the diameters, while the friction increases as the diameters, directly. There are other sources of

friction, but the above examples will be sufficient to prove that, although there appears a discrepancy in the reported duties of the Cornish engines, as *friction* is not taken into the account, it does not *necessarily* follow that an engine, whose *reported* duty is great, should be, in fact, superior to one whose *reported* duty is less.

In addition to this, the *reported* duty, of the same engine doing the same work, may vary 7 or 8 per cent. at different times, merely in consequence of the different quality of the coals supplied.

Particulars of the Cornish engines, showing that they are not inapplicable for waterworks purposes:—

First—The steam is raised to about 40 lbs. pressure upon the square inch, and the admission of it into the cylinder is cut off when the piston has travelled one-third, one fourth, one-eighth, or even one-tenth of the length of the stroke, according to the work to be done, and during the remainder of the stroke the expansive power of the steam is exerted.

Second—The boilers are tubular, in some instances having an internal tube, *b b*, and a feed tube, *c c*, as represented in the accompanying drawing; in other instances these tubes are not introduced. I consider their introduction an improvement; the quantity of surface of the boiler exposed to the action of the fire, or heat of the flues, in proportion to its cubic contents of water, as compared with the Boulton and Watt boiler, is as 60 to 37, or as 3 to 2 nearly.

Third—All those parts of the boilers, cylinder, and pipes containing steam which are exposed to the air in most engines, are in the Cornish engines completely cased with a non-conducting material, which, in fact, renders the engine and boiler houses, where this system is carried to its full extent, as cool as the inside of a dwelling-house where there are only ordinary fires. Very little heat is lost when the engine stands still for twelve hours, and if it is necessary to start it during the night, or in case of emergency, scarcely any time is lost in raising the steam, and one-fourth the fuel only is required after the engine has been standing all night; whereas, in the common engines and boilers, where every vessel containing steam is much exposed, it takes from twenty minutes to half an hour, firing hard, to raise the steam.

Fourth—The steam and exhausting valves are (what are termed in the county) "double beat valves;" they may be said to combine the advantages of the circular and slide valves, although not constructed like either; the effect is, however, that a man, who would not have strength to raise the valves of a 36 inch cylinder made according to the ordinary construction, may with perfect ease work the valves of an 80 inch cylinder, as made in Cornwall; the exhausting valves and the pipes leading to the condenser are made of much greater area than ordinarily.

Fifth—The length of the stroke is greater, and the number of strokes per minute fewer, than in other engines.

Sixth—The water is raised by a solid plunger working through a stuffing box, instead of a packed piston or bucket, so that, the packing being external, any leakage is detected immediately, without the delay attendant upon examining and fresh packing the ordinary packed pistons; and the pump may thus be made always to do its full duty, instead of, as is frequently the case, the water escaping by the piston when the packing becomes imperfect, or through bad valves when a bucket is used, and which cannot be detected until it increases to such an extent that the irregular working of the engine denotes it.

Seventh—The valves of the pump, instead of having their hinges in the centre, obliging the water to pass through a confined space between the valve and the side of the valve box, and lying almost flat upon their seats, making it necessary for them to rise much higher than would otherwise be required to deliver the quantity of water, and causing upon its descent so forcible a blow as to render it necessary to admit air under the valves, partially destroying the vacuum in preference to shaking the engine to pieces, and with openings through them of one-half or two-thirds the area of the pump barrel, rendering much greater power requisite to overcome the friction of the water in its passage through them,—instead of this arrangement, the valves are hung at the circumference of the circle and open in the centre, and the lower ones are fixed directly under the pump barrel;—they lie at a considerable angle to the horizon, so that a less rise of the valves is sufficient for the passage of

the water, and the openings are made *equal* in area to the pump barrel. The effect is, that, without the admission of air, as is absolutely necessary in the ordinary pumping engines, and which diminishes the quantity of water raised per stroke, although working under more than three times greater column of water, they make no blow of any consequence upon the return stroke.

Eighth—The cataract is used, by which the engine may be made to work from 1 to 12 strokes per minute, as may be required, consuming coals nearly in proportion to the number of strokes; the best rate however is about 5 or 6 strokes per minute. The cataract is peculiarly applicable to engines used in draining mines, where the work to be done increases in proportion as the working of the mine progresses: and also to engines for water-works where the demand increases every year, and the power must increase in proportion. To illustrate this, when one of the London water-works was first established, there were two engines of 30 horses' power, afterwards one of 20 horses' power, and afterwards one of 80 horses' power erected; the number of engines increasing as the demand for increased supply Now if an engine upon the Cornish plan had been erected, which at 8 strokes per minute had been equal to 160 horses' power, then by working it 3 strokes per minute it would have been equivalent to the two 30 horse engines only, at 4 strokes to the two 30 horse and the 20 horse engines, and at 8 strokes equal to all of them. In this case one engine would have answered the purpose, and the saving that would have been made in engines, boilers, buildings, &c., wear and tear of machinery, labor, and current expenses, is evident.

Ninth—As the extent of pipes in a water works district increases, the amount of friction must also increase, and the engine must work under a greater pressure; there must consequently be a greater load upon the pump. The ordinary engines would not be able to work under this increased load, and a smaller pump must be used; but as this would not give a sufficient quantity of water a new engine must be erected, and this has been the case hitherto; whereas, in a Cornish engine, by increasing the pressure of steam, or by working a less proportion of the stroke by the expansive force of the steam, this increase of expense may be much longer deferred.

Tenth—The Cornish engines, in which the before named arrangements have been adopted, do about three times more work, with the same quantity of fuel, than the common water-works pumping engines. As this has, however, been declared impossible, I will endeavor to prove the contrary by a comparison of the two engines.

The common water-works engine is worked with steam at a pressure generally of two and a half or three pounds above the pressure of the atmosphere; the admission of steam is not cut off until the piston has made three-fourths or seven-eighths of its stroke, and the principle object in view in cutting it off at all is to make the danger of the piston travelling too far, and the chance of breaking the bottom of the cylinder, beam, or parallel motion, less.

On the 18th of February last, I tried the power of an engine upon this construction; the experiment lasted one hour, and 469 lbs. of good Holywell Main large coals were used. The diameter of the cylinder was 60 inches, length of stroke 7 feet 9 inches; the engine made 869 strokes in the hour, or 14.48 strokes per minute; the pressure of steam was $2\frac{1}{2}$ lbs. per square inch above the pressure of the atmosphere, which was $14\frac{3}{4}$ lbs.; the vacuum in the condenser equal to $13\frac{1}{4}$ lbs.; the diameter of the pump was 27 inches, the length of the stroke 7 feet 9 inches, the pressure upon the pump piston equal to a column of water of 115 feet in height, load upon pump piston 28,577 lbs., equal to 10.1 lbs. pressure per square inch of the steam piston; as the pressure of the steam, minus $1\frac{1}{2}$ lb. for imperfect vacuum in the condenser, was $15\frac{3}{4}$ lbs., the friction of the engine must have amounted to 5.65 lbs. per square inch.

The steam used in the hour may be found thus:—the area of cylinder was 19.63 square feet, and the steam was cut off at 1 foot 3 inches from the end of stroke, making length of the stroke for the dense steam 6 feet 6 inches, which, multiplied by the area, gives 127.6 cubic feet per stroke, add $\frac{1}{10}$ for loss of steam per stroke in the vacancies of the cylinder, making a total of about 140 cubic feet of steam per stroke, which, multiplied by the num.

ber of strokes per hour, (869 × 140,) is equal to 121,640 cubic feet of steam, generated under a pressure of 35 2 inches of mercury, at a temperature of about 222° Fahrenheit.

The "duty" p rformed was 34,467,052 lbs. raised 1 foot high with a bushel, or 84 lbs. of coals.

The power of the engine during the time of trial was $(28{,}577 \times 7.75 + 14.48 \times 33{,}000)$ (lbs. load. stroke. strokes per min.:) equal to 97.2 horses' power.

The steam used was equal to 1251 cubic feet per hour per horses' power, to produce which, at a temperature of 222° Fahrenheit, would require about 0.856 cubic foot of water, and to convert this quantity of water into steam at 222°, it *required*, 4.82 lbs. of coals.

Now supposing the admission of steam was cut off when the piston had travelled one-sixth of its stroke, the operation of its expansion, and the pressure at different stages, and mean pressure of the whole, will be seen by the following Table.

	lbs. pressure per square inch.
During $\frac{1}{6}$th of the stroke dense steam was admitted at a pressure of	17.25
At $\frac{2}{6}$ of the stroke the steam had expanded to twice its volume, and the pressure was reduced to	8.62
At $\frac{3}{6}$ ditto ditto three times	5.75
At $\frac{4}{6}$ ditto ditto four times	4.31
At $\frac{5}{6}$ ditto ditto five times	3.45
At $\frac{6}{6}$ ditto ditto six times	2.87
	6)42.25
Mean pressure per square inch	7.04 lbs.

If the steam had worked dense through out, the pressure would have been 17.25 lbs. throughout, but 6 times the quantity of steam would have been required; whereas, with one-sixth the quantity of steam, the mean pressure is 7.04 lbs. per square inch, showing that as the quantity of fuel required is in proportion to the steam generated, by working the engine thus expansively the effect is as 2.4 to 1.

If, however, the steam was to be generated under no higher pressure than 17.25 lbs. per square inch, it would be necessary to have the area of the steam cylinder 2.4 times greater than the one hereinbefore mentioned, to raise the load; that is to say, a cylinder of nearly 93 inches in diameter, with 7.04 lbs. pressure per square inch, instead of a cylinder 60 inches with 17¼ lbs. pressure per square inch. As this would obviously be disadvantageous, inasmuch as there would be a great increase of friction, the practice of using steam of higher temperature, say from 35 lbs. to 40 lbs. above the pressure of the atmosphere, has been adopted in Cornwall. In fact, the general dimensions for a Cornish engine to do the work hereinbefore stated, would probably have been as follows, viz.

Diameter of cylinder	57 inches.
Length of stroke	10 feet.
Number of strokes per minute	7
Diameter of pump piston	34 inches.
Length of stroke	10 inches.
Load on pump piston	45.805 lbs.
Load per square inch on steam piston	18 lbs.

In addition to the foregoing, which only shows the advantage to be 2.4 instead of 3, as I have before stated it to be, there is a very considerable saving in fuel in consequence of the casing, which saving is of course greater in proportion in engines where steam of a high temperature is used; and there is also less friction, in consequence of the slow motion of the engine, and from the other causes already stated, which, in my opinion, are fully equal to make up the difference. It is hardly necessary to observe here, that the more the steam is worked expansively the greater is the proportional advantage.

The principle of expansion is not *new*; it is the extent to which it has been carried, especially of late years, by the successful adoption of steam at a higher temperature than is used in the common condensing engine, which is new.

The late Mr. Watt took out a patent in 1782 for working steam expansively, and in his specification, dated March 12th, 1788, he says, "My new improvement in steam or fire engines, consists in admitting steam into the cylinder of the engine only during some certain part or portion of the descent or ascent of the piston, and using the elastic forces wherewith the said steam expands itself in proceeding to occupy lar-

ger spaces as the acting powers on the piston, through the other parts or portions of the length of the stroke of the piston."

He then shows, that if steam of 14 lbs. pressure is admitted into a cylinder, and cut off at one-fourth of the length of the stroke, that at half the stroke the pressure is reduced to 7 lbs.; at three-fourths of the stroke to $4\frac{2}{3}$ lbs.; and at the end of the stroke the steam would be reduced to $3\frac{1}{2}$ lbs., or one-fourth of its original power. He then shows that the sum of all these powers is greater than 57-hundredth part of the original power multiplied by the length of the stroke, and consequently, that one-fourth the steam, thus used, produces more than half the effect that four times the quantity would have produced if worked dense through the whole stroke.

He then says, "consequently, the said new or expansive engine is capable of easily raising columns of water, whose weights are eqaal to 5 lbs. on every square inch of the area of its piston, by the expenditure of only one-fourth the contents of the cylinder of steam at each stroke."

He had previously shown that the engine working dense steam might be loaded to 10 lbs. per square inch of the area of the piston.

And lastly, he says, "and though, for example, I have mentioned the admission of one-fourth of the cylinders full of steam, as being the most convenient, yet any other proportion of the content of the cylinder will produce similar effects, and in practice I actually do vary the proportions as the case requires."

The casing of the cylinders, boilers, and steam pipes is not new either, but I have never seen it carried to the same extent as it is at present in Cornwall.

Great and deserved credit is due to the perseverance, energy, and ingenuity of the Cornish engineers for bringing the expansive engine to the state that it now is, and for the daily improvements which, although taken separately may appear trivial, are in the aggregate of great importance.

I will conclude this portion of my observations by referring you to the printed Report of the public trial to which the Fowey Consols engine before mentioned has been exposed, in which it is stated, that the engine raised above 125 millions of lbs. one foot high, with 94 lbs. of coals, or nearly 112 millions with 84 lbs., or an imperial bushel. This is the greatest performance of any engine; and the engineers, Messrs. Petherick and West, cannot fail to receive the credit they so richly merit.

Although it is admitted by some engineers in London, that the reports from Cornwall may be true, and that water may be raised out of the *mines* at the expense of power reported, nevertheless, they assert that it is not applicable to water-works purposes, on account of the variation in the pressure.

That there is a variation in the pressure where the water is forced into the pipes directly from the engine is certain, and it must be dependent upon the quantity of water drawn from the mains by the tenants, and as this varies, so the pressure must vary—the variation is either not very great, or is periodical; thus the pressure during the day is greater than at night, and during summer greater than in winter. In either case, the increased pressure arises from the circumstance of a greater quantity of water having to be forced through the same pipes in a given time; consequently, the velocity must be greater, and as a matter of course the friction, which increase of friction must be overcome by increased power. If the only variation was a periodical one, and at each period the pressure was steady, then reservoirs at different altitudes, to suit the different pressures, would supply the district as well as a steam engine; (even this position has been disputed;) but as at every stroke of the engine there is a slight variation, not amounting, however, during any of the periods before named to more than 5 or 6 feet, then, as the mean difference is $2\frac{1}{2}$ feet, and in case of a reservoir it would be necessary to have its altitude equal to the greatest pressure, there would be a loss amounting to the difference between the mean and the greatest altitude. It should be observed, that the *greatest* portion of the metropolis supply is from summit reservoirs.

Supposing that a Cornish engine could not be worked in the same manner as a London water-works engine, which, however, is not the case, and that it were necessary to work it under a fixed pressure, varying, however, at *given* periods, the loss, as before shown, is trifling. Suppose it to be $2\frac{1}{2}$ per cent.; or taking the variation at

20 feet, instead of 5 feet, the loss would then be 10 per cent.; the gain, however, by adopting the Cornish engine, is 300 per cent.

There would, however, be an advantage in working either a Cornish or a London pumping engine under a fixed pressure instead of a variable one, and much less danger; for in all single engines, working under a pressure that varies, and where from the great extent of mains and services there is great liability to accident from the bursting of pipes, or sudden shutting off an important main by accident or design, the danger of the piston travelling too far, and thereby breaking the beam, or the cylinder bottom, is very great, and the only safeguard is the vigilance of the engine-keeper, who, if he is constantly watching, may take the engine "in hand," in case of a sudden variation in its speed, and thus prevent the accident which might otherwise have disabled the engine. This is not by any means a hypothetical case.

It would therefore be the safest plan to work the engine under a fixed load, even at the loss of a little power, if at the same time the liability to accident was rendered infinitely less.

In most cases, therefore, where the pressure under which the engine works is known, *and it ought to be known*, I should recommend the adoption of a standpipe, the water rising from the engine in one pipe, and flowing over either at the top, or through communicating pipes, at any level required, into the descending pipe communicating with the mains in the district. The engine might then work under a regular load; any fracture of the pipes in the district would not affect the engine; its only liability to accident being from the fracture of one leg of the standpipe, which of course could be provided against by extra strength of materials.

Although I have shown how (upon the supposition of the variation in pressure being an objection to the application of the Cornish engine to water-works purposes) the supposed difficulty may be overcome, I by no means intend to allow that the engines in Cornwall are not subject to chances of as great and even greater variation; for if any valve breaks, which is very likely to happen where there are so many pumps at work, if the water at any time fails, and air is suddenly admitted through the suction-pipes, &c., &c., in all such cases, the resistance to the power of the engine is reduced, and if the parts of the engine were not made strong enough to resist the force of a sudden blow, fracture would take place; but they are generally, and ought always, to be strong enough.

In conclusion, I beg to observe, that if the Cornish engines do the work that it is stated they do, and if they are applicable to water-works purposes, of both of which I have no doubt, then the saving is most important; for supposing instead of *three* engines, consuming 3000 tons of coals per annum, *one* could be erected doing the work of the three, and only consuming 1000 tons, assuming the price of coals delivered to be 18*s.* per ton, the saving in coals alone, without reference to the savings in the reduced number of engine-keepers and stokers, the current expenses of one engine instead of three, the wear and tear of machinery and buildings, would be £1800 per annum.

Nov. 4, 1835.

Preserve your Receipts, *especially* for newspapers, and periodicals, as such accounts are more numerous than in most other kinds of business and therefore errors are more like to occur. To avoid errors in our accounts, and to give the parties interested an early opportunity to correct them should they occur, we have adopted the plan of publishing in each number, the name, residence, and *date paid to*, of those who have paid during the month—and we request early information should error be detected by subscribers.

Payments in Advance.—Our friends who have so promptly paid in advance, for the current year of the Magazine, will please accept our thanks. Those who have been too *busy* to think of such a *trifle*, will have the goodness to receive "*in advance*," our thanks, and then we shall have no occasion to repeat the expression on receiving their favors.

To those who have been so constantly engaged in *business* as to *omit* to pay for *previous* years, we will merely say—it will afford us much pleasure to receive the amount and record their names as paid to *January* 1838.

M. Degousse has succeeded in piercing a fourth Artesian Well, at Meaux. The depths of the bores of these wells are from 164 to 295 feet English, and the water rises to from 3¼ feet to 16 feet 4 inches English. The quantity obtained at the Fulling Mills is 66 English gallons a minute, and that at the Seminary 37 gallons. The water is very soft, and has been proved by an analysis to be fit for every purpose.

M. Aime Grimaud has within these three days made an experiment on the Seine of a new invention, by means of which vessels may be impelled across the seas in every direction without the use of fuel. Additional force will be given to windmills, and artificial falls of water may be formed so that such provinces as are now deficient in this necessary of life may be supplied. The new machine is composed of several wings forming together a wheel which is supported by a vertical mast that gives a motion to a transversal beam, at each extremity of which is a paddle wheel. This machine is so constructed that it acts in every direction of the wind, and has all the force of a steam-engine. M. Grimaud has succeeded in making his way up the river against the current, which was strengthened by the late floods, and in traversing in it all directions, even in the teeth of the wind.

COCHRAN'S MANY-CHAMBERED GUN.

We always take pleasure in speaking of important inventions, even though they may not tend *directly* to the construction of Railroads or Canals—and therefore we give the following testimonials of the value of Mr. Cochran's improvement in *fire-arms*, with a drawing and concise description of the improvement.

The *chambers*, or receptacles for the charge, are in the periphery of a cylinder of about 4 inches in diameter, and ⅞ths of an inch thick, which revolves horizontally on a pivot, bringing each chamber alternately in a line with the barrel; on the under side, and about equidistant from the periphery, and centre of the cylinder is placed a small cone to receive the percussion cap. There is a cone to each charge, having a communication with the powder. When the cylinder is charged,—each having *nine* charges,—the caps are put upon the cones, and then the cylinder is put in its place and secured there by a spring.—When in its place, each chamber, or charge, points in a different direction, and each cap is perfectly protected from explosion, except the one communicating with the chamber in line with the barrel, and after discharging which, no further explosion can take place without moving a spring, which permits the cylinder to make the *one-ninth* of a revolution, thereby bringing another chamber, or charge, in line with the barrel. A person familiar with the use of this gun, having *extra* cylinders in his belt, can easily make *thirty shots in a minute*; as he would only remove it from his face *three* times, to make 36 shots.

The great facility with which it can be discharged, is not, as will be perceived, on reading Capt. Gordon's Letter, its highest recommendation. The *certainty* of explosion, even after long exposure in damp weather, is of the first importance; a quality which it appears to possess in an eminent degree.

The accompanying drawings show the positions of the cylinder in which is represented the chambers and the cones for the caps.

If further evidence, than the annexed letters from gentlemen every way qualified to give a correct opinion, is required, it can be furnished, by actual demonstration, to those who will call on Mr. Cochran, or Messrs. Richards & Richardson, of this city, who are the Agents of the Company engaged in the manufacture of the article.

☞ A specimen of this beautiful article may be seen at this office—where orders will be received for *Rifles* or *Pistols*.

I have examined, and seen fired the ingenious invention of Mr. John Cochran's many-chambered gun, and, have no hesitation in saying, it combines simplicity, neatness, and at the same time, great despatch; and for all the uses of warfare, should approve of it highly.

ANDREW JACKSON.

Washington, Jan., 1837.

I cheerfully unite in the above testimonial, of Mr. J. W. Cochran's gun.

ANDREW JACKSON, JR.

—

WASHINGTON CITY, Jan., 1837.

We, the undersigned, have witnessed the experiments made by Mr. John Cochran, with his many-chambered gun, and are of opinion, that we have never seen any thing to compare with it; as to its simplicity, safety, and the rapidity and certainty of its firing; it can be fired thirty times in a minute, with great effect; it is in our opinion, one of the most formidable weapons ever invented.

D. S. CLINCH,
G. J. DRANE, U. S. Army,
WM. P. DUVAL,
WM. COST JOHNSON,
S. WARRINGTON,
SAM'L. C. REID,
CH. G. RIDGELY.

—

WASHINGTON, Nov. 21, 1836.

COLONEL,—The enclosed report of Lieutenant Scott, which I have the honor to submit, fully confirms the high estimate I had formed of Mr. Cochran's gun, from the experiments instituted by me, on Saturday, in conformity with your instructions.

Under my supervision, the gun was loaded and discharged five hundred times; the results proving its great accuracy, safety, and facility of loading and firing. My attention was particularly called to the apparent danger of ignition, from the contiguity of the charges. But, from the experiments freely made by Mr. Cochran, by placing loose powder in the chambers over the balls, and around the caps, I am convinced that my apprehensions were unfounded.

I do not hesitate to say, that with my closest scrutiny, I could not discover any objections to Mr. Cochran's invention. It will be well to remark, that the gun was discharged in all, one thousand and eight times, without being cleaned, and without missing fire.

The flattened balls accompanying this, were fired through an inch-plank against a brick wall, at a distance of 150 yards.

I am, Sir, very respectfully,
Your Obe't. Ser't.
(Signed) GEO. D. RAMSAY.
Capt. of Ordnance.

COL. T. BOMFORD, U. S. Ordnance.

For Mr. Cochran, with the compliments of GEO. D. RAMSAY.

—

WASHINGTON ARSENAL, Nov. 22, 1836.

SIR,—Having been present at the test of the gun with revolving Cylinders, invented by you, and being a witness to the many experiments, which were made on Saturday, the 19th inst., at this place, I can but attempt to express the great satisfaction it afforded me, to see the following successful trials made by you:

Firstly, As a smooth-bored gun, in regard to the accuracy with which it shoots a ball, I must say that nothing of the kind, that has heretofore come under my observation, can be compared with it; for at a distance of fifty yards, the size of a dollar was struck three times in succession.

Secondly, When the comparison (or rather contrast) was made between your gun and Hall's Carbine, as to the depth of penetration into pine wood, I was most astonished to see the great difference between the two: At the distance of fifty yards, your gun, the first shot, penetrated 4 inches, the second shot, 3 inches and 8-tenths, the third shot, 3 inches and 8-tenths; whilst Hall's Carbine at the distance of fifteen yards, only penetrated 2 inches and 8-tenths.

Thirdly, As to the speed with which it

was fired, while Hall's Carbine could only be loaded once, your Gun completely discharged its Cylinder containing nine charges, in the space of six seconds.

Fourthly, As to the certainty of discharge, in firing 1008 charges, not one cap failed, and when double shotted, and fired, no recoil was perceptible.

In fact, your gun, for simplicity, accuracy, and certainty, together with its other inestimable qualities, is, in my opinion, beyond improvement, and may be called a most complete fire-arm.

With very great respect,

I am, Sir, &c.,

JOHN M. ST. JOHN,

Master Armorer, &c., Washington Arsenal.

To JOHN COCHRAN, Esq.,

Brown's Hotel, Washington City.

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The piece was fired this morning 500 times, making in all 1008. It is in the same order it was previous to the discharging it. Water was put into the chambers, and left for one hour and ten minutes.—Afterwards, it was discharged in the same manner as the others, without the least difficulty. It fires with great accuracy. I tried it with Hall's carbine, both being loaded, the firing was commenced, during the discharging of the nine chambers, the carbine could only be loaded once, not a cap missed. At the distance of 150 yards, charge 10 grains of powder, the ball perforated an inch pine board, and was flattened against the brick wall. For simplicity, it surpasses any thing of the kind I have yet seen; and as a fire-arm, its qualities can be summed up in three words: It is perfect.

J. B. SCOTT, 1st. Lieut. 4th Infantry.

Washington Arsenal, Nov. 20, 1836.

Mr. Cochran fired the nine chambers in *six seconds.*

J. B. SCOTT, 1st. Lieut. 4th Infantry.

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COCHRAN'S GUN TESTED IN A BATTLE WITH THE SEMINOLES, IN FLORIDA, BY CAPTAIN GORDON.

NEW-YORK, March 17, 1837.

SIR,—Having had very ample opportunities of testing the very great superiority of your "Many-Chambered" gun, it affords me great pleasure to state, for the public information, that I consider it far superior to any other now in use. Its peculiar adaptation to the purposes of war, gives it just and strong claims to the patronage of the General Government. I do not hesitate to declare it as my firm and decided opinion, that one hundred men, armed with your gun, would be equal, in point of efficacy, in battle, to one thousand armed with any other. Its superiority for hunting purposes is equally great, and cannot fail to secure for it the public favor.

The astonishing capability of your gun to resist dampness, or injury of its charge, when loaded, I consider of the greatest importance. A very striking and satisfactory instance of this manifested itself in the late battle wit.. the Seminoles, on Lake Monroe. Your gun had at the time been loaded at least two weeks—had been taken out on one or more excursions, and exposed to the dampness of the atmosphere, which in that country is very great, and such other causes as had made it necessary to discharge and re-load all or most of the other arms similarly exposed,—yet, under these circumstances, without re-loading, yours went off in every instance, (the whole round of chambers,) as if recently charged. The simplicity of the machinery, and the great power with which it throws its balls, will justly enhance its estimation with all who will take the trouble to examine and make trial of them.

In conclusion, I will repeat, that I have no hesitation in giving it as my firm conviction that your's is by far the most efficient fire-arm ever offered to the public, and every way worthy of confidence and patronage.

I am, Sir, very respectfully,

Your most ob't. humble serv't.,

W. GORDON,

Captain U. S. Dragoons.

To Mr. JOHN COCHRAN, New-York.

RAILROADS AND CANALS IN ILLINOIS.

We ask for the following communication, an attentive perusal. It illustrates, with great force and truth, the pervading spirit of the age; and it must surely satisfy those who are still incredulous as to the high destinies of that young State, that ILLINOIS in a few years will be second, and but for her

unrivalled *city*—only second, to the State of New York.

We are obliged to "The Far West" for the interest he expresses in the success of this Journal—and we are disposed to hold him to his very liberal offer to "keep us informed of the prospects of the public works in the State." We hope to hear often from him especially in relation to the probable connection of the public works in Illinois with other great works in other States.

GRAND SYSTEM OF INTERNAL IMPROVEMENT IN ILLINOIS. The Legislature of Illinois has recently adjourned, after passing an act to *establish and maintain* a general system of Internal Improvement. A Board of Commissioners of Public Works is appointed, who are authorized and required to adopt such measures as may be necessary for constructing and completing the following works :—

A Railroad from Cairo, at or near the the confluence of the Ohio and Mississippi rivers, to Galena on the Upper Mississippi; to pass through Vandalia, Shelbyville, Decatur and Bloomington, intersect the southern termination of the Illinois and Michigan canal, and from thence through Savanna to Galena. Ranging through the centre of the State its entire length, five hundred miles.

A cross Railroad from Alton on the Mississippi to Mount Carmel on the Wabash, via. Edwardsville, Carlyle, Salem, Fairfield and Albion, one hundred and seventy miles, with a diverging fork from Edwardsville to Shawneetown on the Ohio, one hundred and fifty miles.

A cross Railroad from Lower Alton, via. Upper Alton and Hillsborough, intersecting the central Railroad at Shelbyville, thence via. Charleston and Paris, to the State line in a direction for Terra Haute, two hundred miles.

A cross Railroad from Quincy on the Mississippi, to the State line, near La Fayette, Indiana, via. Columbus, Clayton, Mount Sterling, Meredosia, Jacksonville, Springfield, Decatur, Sydney and Danville, two hundred and fifty miles.

A Railroad from Peoria on the Illinois river to Warsaw on the Mississippi, through Canton, Macomb and Carthage, one hundred and twenty miles.

A Railroad from Bloomington, a point on the great central Railroad to meet the Railroad from Warsaw at Peoria, and a point from the same at Mackinaw town via. Tremont, to strike the Illinois river at Pekin, seventy-five miles.

A Railroad from Belleville via. Lebanon to intersect the Alton and Mount Carmel Railroad, twenty-five miles.

Specific appropriations are made for each route, besides which, two hundred and fifty thousand dollars are appropriated for the improvement of the great western mail route from Vincennes on the Wabash to St. Louis :—and six hundred thousand to improve the navigation of the Great and Little Wabash, the Illinois, the Kaskaskia and Rock rivers, including a portion divided among certain counties to be used at their own discretion.

It will be seen that beside the great central Railroad, which touches the Missisippi at Galena, and of its confluence with the Ohio, there are four Railroads which run entirely across the State, besides one nearly two hundred miles in extent which intersects the Central Railroad, striking the Illinois river at two points. There are three terminations at the Indiana line; one near La Fayettte, which opens a line of communication with New York, by the Maumee and Erie canal; one near Terra Haute, a point of the National road, and of intended communication with the Central canal of Indianna, and with Evansville, by a Railroad, and one at Mount Carmel, below the rapids of the Wabash.

There are the terminations on the Ohio; one at Shawneetown, and one at or near the mouth of the river.

There are four terminations on the Mississippi, beside the one at its confluence; viz. Galena, the centre of the lead region on the Upper Mississippi; at Warsaw, below the Lower Rapids; at Quincy, and at Alton. Besides these terminations on the Mississippi, there is now organized, under a very liberal charter, a company who are about to construct a Railroad, intersecting the Quincy and La Fayette main cross Railroad, via. Springfield and Carrollton, to strike the the Mississippi at Grafton, at the confluence of the Illinois and Mississippi rivers, a most important point.

It should be remarked that less than twenty-five miles would connect the great Central Railroad, with the Ohio river at a point above the mouth of Cumberland river from whence a route has been projected through Princeton and Hopkinsville in Kentucky, and Clarksville Tennessee to Nashville, a distance of one hnndred and thirty miles only, to effect the most important junction with the Nashville and New-Orleans Railroad. We have thus about one hundred and fifty miles of Railroad only to provide for to *open a direct Railroad communication between New Orleans and the Upper Mississippi and the Great Lakes!* A distance of nearly twelve hnndred miles, through the heart of the most fertile region on the face of the globe.

To the prudent calculators of the North, the magnificent enterprise of the young State of Illinois may seem premature or extravagant. We beg them however to reflect that we have a territory equal to that of the State of New-York, the *whole of which*, is of *extraordinary fertility*. That the enhanced value of the land in the immediate vicinity of the projected Railroads, will pay their cost *four times over*. That our population, not only in numbers, but in wealth, enterprise and intelligence, is rapidly increasing; and, what is a more important consideration perhaps than all others, such improvements are in acccordance with the spirit of the age, and *our whole people call for them.*

THE GREAT WEST.

Railroads appear to be advancing more rapidly in Germany than in France. That from Nuremberg to Furth transports weekly 18,000 travellers; that from Leipzic to Dresden will be opened immediately, and will join the Munich railroad at Augsburg, and in a few years will extend as far as Trieste. The subscription list for the railway from Magdebourg to Leipzic, the capital of which is fixed at 16,400,000 fr. was filled in two days. A company is being formed for the establishment of a railroad between Hambourg, Berlin, and Magdebourg; it will extend 80 leagues, and will unite three towns with a population of five hundred thousand inhabitants, besides transporting an immense quantity of goods.

TRIUMPH OF RAILWAYS.—It was matter of some curiosity whether or not the engines could continue to work upon the Newcastle and Carlise railway during the continuance of the snow upon the road. The possibility of so working was fairly put to the test on the 26th ultimo, and the utility of railways demonstrated in a most striking manner.—In the deep cutting through the Cowan Hills, the snow had drifted to the depth of four or five feet; and when the Hercules came down on Monday morning, great number of country people had assembled to see how she would act in such an emergency, and to render any assistance which might be necessary. On arriving at the spot the engine made no bones of the matter, but dashed right into the drift, clearing its way through, apparently without the slightest difficulty, the snow at the same time flying over the top of the engine chimney like foam from the broken waves of a violent sea; and notwithstanding this and other similar obstructions, the train came down from Greenhead (twenty miles) in an hour and a quarter. The trains have continued regularly to keep their time, while all communication by common roads has been more or less most seriously obstructed if not entirely cut off for a time.—[Carliles Patriot.]